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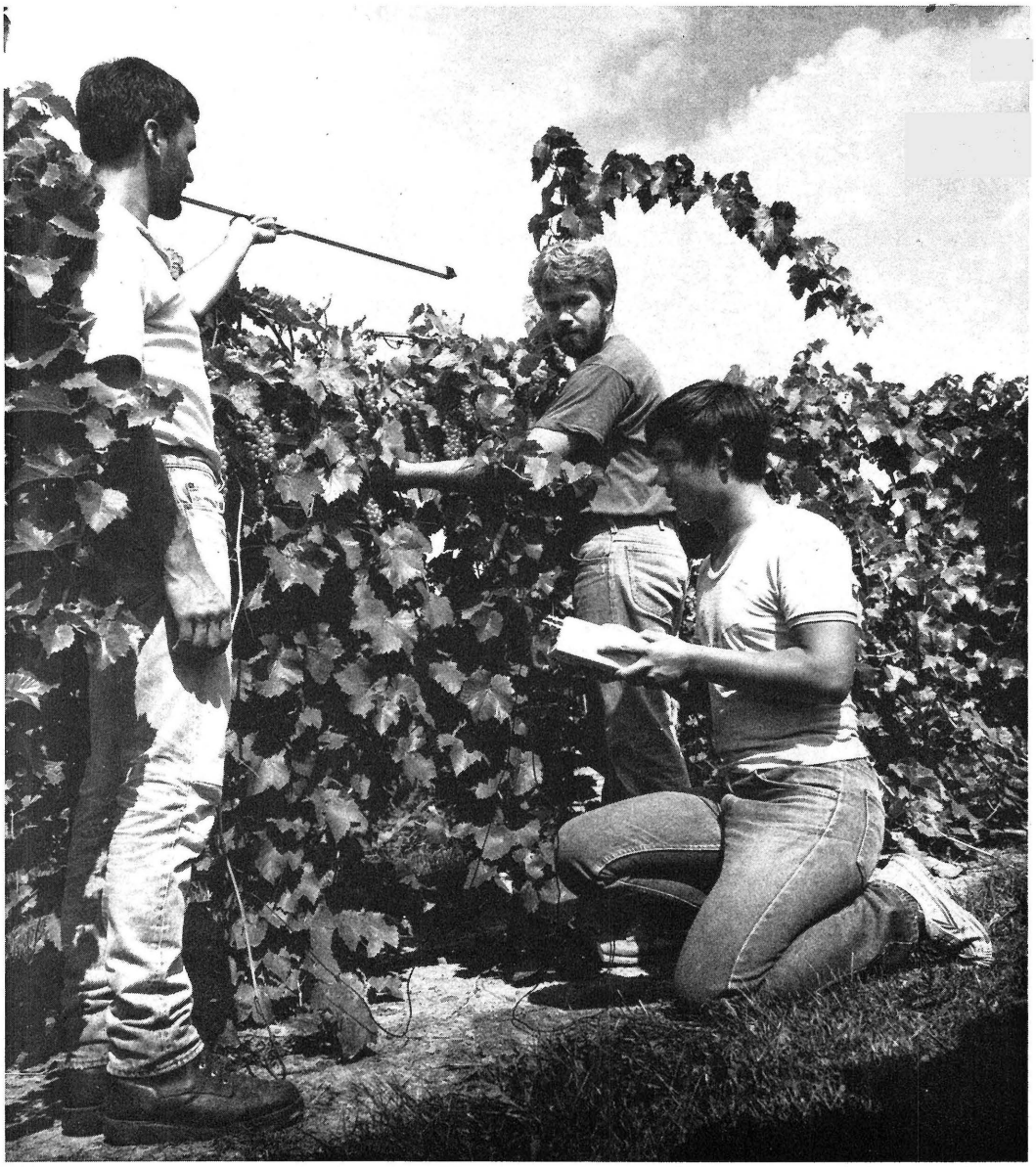
Fruit Crops 1987: A Summary of Research



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INFLUENCE OF GROWTH REGULATORS ON APPLE SPUR QUALITY AND TREE PERFORMANCE

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INTRODUCTION

Recent work (1,6) has shown the localized importance of high quality apple spurs for optimum fruit set, fruit size, and high fruit Ca levels (6,10). Yield of nine apple cultivars over a 17-year period was highly correlated to spur quality (13). A high quality spur has been defined as one with a large terminal bud, large number of leaves/spur and corresponding large leaf area, and a high specific leaf weight (SLW) (1,13,16). Factors associated with the development of high quality spurs include light environment (1,5,14,15), pruning (5), and nitrogen levels (5), but these factors do not totally explain why spurs in close proximity vary widely in quality (6). The series of six studies reported here evaluate the potential of growth regulators to influence spur quality. Two new materials that are triazole compounds which inhibit sterol and gibberellin biosynthesis (4,9), and thus, retard growth were particularly studied. PP333, also called paclobutrazol (PBZ) or Cultar^{TM} is from ICI Americas, Inc., and XE1019 (Prism^{TM}) is from Chevron Chemical Company.

MATERIALS AND METHODS

Experiment 1—Soil vs Spray Applications

Mature 'Millerspur Delicious' apple trees on M.26 rootstock at Overlook Farm (Carroll, OH) were treated as follows with PP333 (50% WP): 1) check, untreated control; 2) broadcast, PP333 (4 grams active ingredient/tree) spray solution (7.6 l/tree) was applied evenly over a 3 m x 3 m soil area November 8, 1982; 3) broadcast, the same as treatment 2, except 8 g ai/tree applied; 4) dormant spray, April 7, 1983, 500 ppm of PP333 was combined with 70 second spray oil (20 ml/l) and applied dilute by high pressure handgun to thoroughly cover the trees; 5) trunk drench, PP333 8 g ai/t mixed in 2 l of water was poured around the base of the tree. The treatments were applied in a randomized block design with five single tree replicates. In addition to shoot length (10 shoots/tree), yield and fruit quality measurements, a sample of five single non-fruiting spurs were taken in September of each year and spur quality assessed by measuring bud diameter, number of leaves, and leaf area.

Experiment 2—Soil Applications by Band or Broadcast

On April 2, 1982, mature 'Red Prince Delicious'/M.26 apple trees growing on a fine, loamy mixed mesic typic fragiudalf soil were treated with PP333 (50% WP) applied to the soil inside the herbicide strip, either by broadcast as a spray in a 3 m x 3 m area centered on the tree, or in a band (61 cm x 3 m) on two sides of the tree approximately 1.3 m from the trunk. The following doses of active ingredient/tree were applied by each procedure: broadcast, 2.0 g, 4.0 g, and 8.0 g; and band, .8 g, 1.6 g, 3.2 g, and 4.0 g. The first 3 band treatments applied equal amounts per unit soil surface as applied in the broadcast treatments. The treatments were applied in a randomized block design with four individual tree replicates. In addition to the data collected in the previous study following defoliation in 1983, the trees were rated independently by three raters for the following characteristics: tree density—1 (open) to 5 (very dense); vigor-upright top growth rated—1 (few and short) to 5 (many and long); spuriness—1 (few) to 5 (many).

Experiment 3—Trunk Drench Applications

On April 19, 1984, XE1019 (10% WP) and PP333 (50% WP) in the 1.5 l water/tree were applied as a drench to the base of the trunk and soil line (see Table 3 for rates). An additional two foliar spray treatments were applied with high pressure handgun beginning at pink (May 10) and at two-week intervals for a total of four sprays. The treatments were arranged in a randomized block design with six single tree replications. Data collected was the same as in other studies.

Experiment 4—Trunk Drench Applications: Flowable vs Wettable Powders

On April 25, 1984, a new liquid formulation of PP333 (50 UL) at three doses (2,4, and 8 g ai/t) was applied as a trunk drench (1500 ml liquid) to vigorous 16-year-old 'Red Prince Delicious' trees on M.26 rootstock and compared to an untreated control and a treatment of the wettable powder formulation (50%WP) at 8 g ai/tree. Treatments were arranged as a randomized block with six single tree replications.

Experiment 5—Applications of PP333

In 1985, PP333 was applied as foliar sprays (2 lb ai/gal) to additional trees in the same block. Tween 20 (1 ml/l) was added to each tank and the sprays were applied with high pressure handgun to drip. The initial spray was made at petal fall, May 5, 1985, with additional sprays (see Table 6 for timing and rates) made at two-week intervals.

Experiment 6—Foliar Applications of Other Growth Regulators

The following treatments were applied in 1984 and 1985 to the lower scaffolds of 25-year-old 'Starkrimson Delicious' trees in a commercial orchard near Pataskala, Ohio to deter-

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mine the influence on fruit size and spur quality of trees in a spur-bound condition: 1) check; 2) urea (2.64 g/l); 3) 6BA [N-(phenylmethyl)-1H-purin-6-amine], 50 ppm; 4) Alar—daminozide [butanedioic acid mono (2,2-dimethylhydrazide)] 1500 ppm; 5) 6BA + Alar, combination of treatments 3 and 4; GA4+7, gibberellic acid, 10 ppm. All treatments were applied with a CO_2 pressurized hand-sprayer with four applications at 10-day intervals beginning when the king bloom was open, except the Alar treatment where a single application was made in late July. The same limbs were treated each year and the treatments arranged in a randomized block with eight single limb replications.

RESULTS

Experiment 1

On the moderately vigorous 'Millerspur Delicious'/M.26 trees at Overlook Farm, PP333 at the 8 g ai/tree dose resulted in a significant reduction in shoot growth the year following application, either as a broadcast treatment or as a trunk drench (Table 1). Application of the trunk drench in the spring dramatically slowed growth (Figure 1) part way through the active period of shoot growth. The influence on vegetative growth from the applications in 1982 and 1983 did not affect growth in 1985. The PP333 treatments had no effect on spur bud diameter or number of leaves/spur, but leaf area/spur was reduced in 1984 by the treatments that significantly reduced growth that year. The only effect on fruit quality was a slight decrease in firmness with the soil broadcast 8 g dose and oil spray treatments and a reduction in the fruit L/D ratio with the trunk drench (data not presented).

Experiment 2

Treatment of very vigorous 'Red Prince Delicious' trees on M.26 with PP333 in early April resulted in no measurable effects the year of treatment (data not presented). However, in 1983, the year following treatment, ratings of tree density, vigor and spuriness indicate that the broadcast 8 g ai/tree dose resulted in a more open canopy, decreased vigor of shoot growth and a more spurry appearance to the tree (Table 2). Actual shoot growth measurements in 1983 show a 43 percent reduction in growth (8 g ai/t), but because of variability, it was not significant. The variability in this study was probably due to lack of sufficient replication (only four) and the inherent variable effect of PP333 applied to the soil. A tree with obvious severe growth restriction exhibited normal growing water sprouts in areas of the canopy or even on a limb with normal growth, while terminal growth in other areas was obviously suppressed (Figure 2).

Spur quality of these 'Red Prince Delicious' trees in 1983 was generally improved as broadcast doses increased and also with band applied material up to 3.2 g ai/tree (Table 2). Spur quality began to decline with banded doses of 4.0 g ai/tree. In 1984 the treatments had no effect on number of leaves/spur or leaf area/spur, but bud diameter had generally the same pattern observed in 1983. The effects on fruit growth were very minimal with a tendency for the higher doses to increase fruit set and a slight reduction in fruit size with the larger crop.

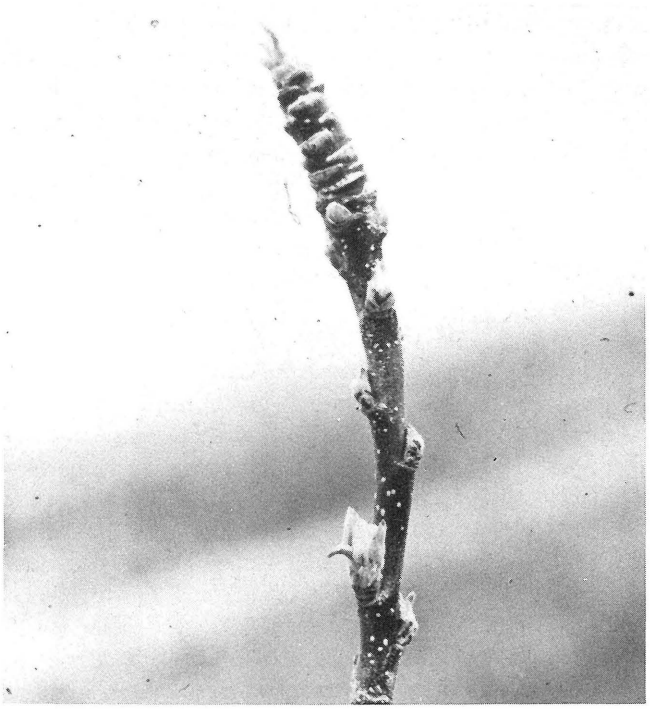

Figure 1. Shoot of 'Millerspur Delicious' showing (A) normal internode length early in the season, but (B) severe restriction with compact internodes late in the season.

Table 1. Influence of several methods of application of PP333 on growth and spur leaf development of 'Millerspur Delicious' apple trees. (Overlook Farm, Carroll, OH).

								Spur Quality 1984		
		Date of	Average Shoot Growth (cm)			Change Trunk Area cm²		Bud Dia.	Leaves/Spur	
Treatment	Rate	Appl.	1983	1984	1985	83-84	84-85	(mm)	NO.	Area cm²
Check			23.6ab*	18.3a	8.9	12.0abc	5.8	2.8	4.0	23.6ab
Broadcast	4 g ai/t	11/82	29.8a	22.8a	9.4	16.1a	11.1	3.1	4.6	29.8a
Broadcast	8 g ai/t	11/82	20.3b	14.2b	15.2	8.4bc	3.9	3.4	4.0	20.3b
Dormant Oil Spray	500ppm	4/83	26.2ab	20.1a	10.0	15.4ab	6.1	3.1	3.8	26.2ab
Trunk Drench	8 g ai/t	4/83	19.0b	4.3c	7.8	5.5c	5.2	3.0	3.4	19.0b

*Means within columns separated by Duncan's Multiple Range % level.

Table 2. Influence of PP333 soil sprays applied in either bands or broadcast under the tree on tree growth and spur quality of 'Red Prince Delicious'/M.26 apple trees, OARDC, Wooster.

							Spur Quality						
							1983				1984		
		1983 Rating*			Shoot Length (cm)		Bud Dia.	Leaves/	Area/ spur	SLW mg/	Bud dia.	Leaves/	Area/ spur
Treatment	g ai/t	Tree Density	Vigor	Spuri-ness	1983	1984	(mm)	spur	(cm^2)	cm^2	(mm)	spur	(cm^2)
Check		3.2abc**	4.2a	2.4bc	35.3	33.5	3.1d	6.4d	85bc	9.8c	3.3bcd	7.1	112
Broadcast	2.0	3.0abcd	3.3ab	2.6bc	30.3	32.1	3.3bcd	6.9cd	77c	10.6bc	3.6bc	7.1	94
	4.0	3.5ab	3.9ab	2.7bc	30.6	39.5	3.5abc	7.7bc	100ab	11.3ab	3.0d	7.6	103
	8.0	2.1d	2.1c	3.8a	20.1	40.8	3.9a	8.1ab	107a	11.8ab	4.2a	8.5	137
Band	.8	3.9a	4.0ab	1.9c	36.1	33.0	3.2cd	6.7cd	81bc	10.6bc	3.1cd	7.9	103
	1.6	3.3ab	4.0ab	2.3bc	31.5	38.4	3.4bcd	7.4bcd	90abc	11.0b	3.4bcd	7.0	102
	3.2	2.6bcd	2.9bc	3.8a	20.6	35.6	3.9a	9.2a	109a	12.4a	3.8b	9.0	128
	4.0	2.2cd	3.1abc	3.1ab	28.7	37.2	3.7ab	7.8bc	95abc	10.6bc	3.6bcd	8.8	118

*Rating System:
Tree Density: 1=open to 5=very dense canopy
Vigor-upright top growth: 1=few and short to 5=many and long
Spuriness: 1=few to 5=many
**Means within columns separated by Duncan's Multiple Range Test, 5% level.

Table 3. Influence of XE1019 and PP333 applications in 1984 on shoot growth and spur quality of 'Golden Delicious'/M.26 apple trees.

					1984 Spur Quality			1985 Spur Quality			1986 Spur Quality			
		Shoot Length (cm)			Bud dia.	Leaves/	Leaf area/ spur	Bud Dia.	Leaves/	SLW	Bud dia.	Leaves/	Leaf area/ spur	SLW
Treatment		1984	1985	1986	mm	spur	cm^2	mm	spur	$(mg/cm)^2$	mm	spur	cm^2	mg/cm^2
Check	— —	26.8ab**	30.7ab	31.3	2.9	6.5	93a	2.7	5.9	7.8bc	2.4c	5.2c	68bc	9.4b
XE1019	TD*2 g ai/t	27.5ab	19.9bc	26.4	2.9	6.9	96a	2.9	6.6	9.6a	2.5abc	6.0abc	62c	9.7b
XE1019	TD 4 g ai/t	29.4a	17.2bc	21.8	2.9	6.3	102a	2.7	6.0	9.5a	2.7ab	6.5ab	74bc	10.0ab
XE1019	TD 8 g ai/t	28.3a	20.1bc	23.0	3.0	6.3	101a	2.8	6.3	9.1ab	2.8a	6.6ab	81bc	11.2a
PP333 50 WP	TD 4 g ai/t	26.4ab	1.5d	22.1	2.9	6.5	103a	3.1	6.7	9.7a	2.8a	7.2a	113a	10.6ab
PP333 10 UL	TD 4 g ai/t	25.7ab	11.4cd	24.3	3.1	6.6	101a	2.9	6.7	9.6a	2.6abc	6.3abc	89b	10.5ab
XE1019	S.05 lb/a	18.7c	26.1ab	24.7	2.8	6.9	69b	2.6	5.9	8.8ab	2.4bc	5.8bc	74bc	9.9ab
XE1019	S.10 lb/a	22.4bc	38.8a	29.3	3.1	6.0	66b	2.7	5.6	7.7c	2.6abc	5.1c	79bc	9.2b

*TD=Trunk Drench; S=Spray
** Means within columns separated by Duncan's Multiple Range Test, 5% level.

Experiment 3

The trunk drenches applied in April of 1984 had no influence on any parameter measured in 1984 (Table 3). XE1019 applied as a spray included the surfactant DC 101 (1.24 ml/liter), which injured the foliage, reduced set and severely russeted the fruit. This injury also resulted in a reduction in shoot growth with XE1019, but no obvious rate effect. The effect of the surfactant was confirmed by application to vigorously growing apple trees in the greenhouse which resulted in similar leaf symptoms. The growth reduction caused by PP333 was considerably greater than with XE1019 with no difference between the two formulations of PP333 utilized. The spray applications of XE1019 had no carry over effects on growth the following year. Of the spur quality attributes, only SLW was increased by all the trunk drench treatments of both materials. PP333 tended to reduce fruit size and increase russet, but other fruit quality attributes were not influenced (data not presented). XE1019 had no effect on fruit size or quality.

Figure 2. 'Red Prince Delicious' trees treated with PP333 showing (A) growth restriction in the lower left with (B) normal shoot extension on an upper limb.

Spur quality was generally improved in 1986 with increasing rates of XE1019 and the WP formulation of PP333 (Table 3). Fruit set tended to be increased by trunk drench applications of both XE1019 and PP333 with increasing effect as rates of XE1019 were increased. None of the growth or fruit quality parameters were significantly influenced by the treatment in 1986. PP333 WP as a trunk drench tended to decrease fruit size partially as a direct effect and partially due to increased crop load.

Experiment 4

Three rates of PP333 applied as trunk drenches of the new flowable formulation to vigorous 'Red Prince Delicious'/M.26 trees in April had no effect on terminal growth, spur quality, yield or fruit quality the year of application. All PP333 treatments increased the number of leaves/spur and SLW the second year with little effect on bud diameter or leaf area/spur (Table 4). Fruit set tended to be increased by all treatments and was significant at the 8 g ai/tree dose. Yield/tree and yield efficiency were increased by all treatments with no influence of rate or formulation and accompanied by an expected reduction in fruit size. Fruit from all treatments had lower L/D ratios with the the greatest effect at the highest rates. In the third year, shoot growth continued to be suppressed (68%) by the 8 g ai/tree treatment, but the numerical reductions from the 2 (20%) and 4 (27%) g ai/tree doses were not significant. All parameters of spur quality tended to be improved by the PP333 treatments. Fruit size and quality were not significantly influenced in 1986 by the treatments.

Experiment 5

Leaf area/spur was reduced by PF, +2, +4 foliar application treatment of Cultar^{TM} at the 560 g/ha rate, but there was no other effect on spur quality in 1985 (Table 5). When PP333 was applied at petal fall, the length to diameter ratio was decreased but later sprays had no effect on shoot growth or change in trunk cross-sectional area. Fruit size or quality in 1986, were not influenced by the 1985 treatments. Spur quality tended to be improved by the treatments, particularly in number of leaves/spur and leaf area/spur.

Table 4. Influence of PP333 applied as a trunk drench in April 1984 on spur quality of 'Red Prince Delicious'/M.26 apple trees.

		1984			1985				1986			
Treatment	Rate g ai/tree	Bud dia. (mm)	Leaves/ spur	Leaf area/ spur (cm^2)	Bud dia. (mm)	Leaves/ spur	Leaf area/ spur (cm^2)	SLW (mg/cm^2)	Bud dia. (mm)	Leaves/ spur	Leaf area/ spur (cm^2)	SLW (mg/cm^2)
Check	——	2.6	6.5	89	3.4	7.0c*	80	7.6b	3.3	6.4b	95ab	9.6b
PP333 5OUL	2	2.7	6.7	86	3.2	7.7b	97	8.8a	3.4	7.9a	102ab	10.0b
PP333 5OUL	4	2.8	6.6	90	3.3	8.6a	107	9.2a	3.8	8.3a	109a	11.1ab
PP333 5OUL	8	3.0	6.6	84	3.2	8.1ab	87	9.3a	3.4	7.4ab	83b	10.7ab
PP333 5OWP	8	2.8	6.2	87	3.2	8.0ab	87	9.4a	3.6	8.1a	78b	11.7a

*Means within columns separated by Duncan's Multiple Range Test, 5% level.

Experiment 6

The various growth regulators applied to the lower limbs for two years on mature spur-bound 'Starkrimson' trees increased fruit set with urea or alar sprays the second year (Table 6). Spur quality or fruit size was not influenced by the treatments in either year of the study.

DISCUSSION

The triazole compounds (PP333 and XE1019) inhibit steroid biosynthesis and retard growth through inhibiting gibberellin biosynthesis (9). Generally, with soil or foliar applications (3,4,16) growth retardation appears the year following application, particularly on soils with high clay and organic content. Most of the studies reported here support these general findings. Interestingly, a fall soil broadcast or spring trunk drench did not affect growth until part way through the active shoot growth period (Table 1 and Figure 1). Significant growth control was obvious in most studies the year following application and it dissipated with little carryover the third year. Higher rates than used in these studies have been reported to produced long-lasting effects (2,7,12) and undesirable effects on fruit (2,7). Generally, effects on fruit in these studies were minimal, except for a shortening of the fruit which has also been reported previously (2,7).

Spur leaf area was reduced in several previous studies (2,7,8,12,17) and it was reduced in one instance in our experiments when severe growth control occurred (Table 1). In others, however, spur leaf area was either not affected (Tables 3, 4) or increased (Tables 2,3,4,5) by the two triazole bioregulators. This likely is due to the lower rates used. It appears from these data that spur quality is increased until the dose of PP333 exceeds a threshhold and then a decrease in spur quality occurs. For example, in the band treatment (Table 2) spur quality in 1983 increased up to the 3.2 g ai/tree dose, but began to decrease at the 4.0 g ai/tree dose. Similarly in 1986 (Table 5) leaf area/spur increased up to the 4 g ai/tree dose, but decreased at the 8 g ai/tree dose. Although the trend appears the same in both studies the upper rate causing the decline in spur quality varies which is likely due to the method of application (banding at the tree periphery in the first instance and trunk drench in the second). The method of application appears to play a major role in the rate needed and response obtained (3,16). Thus, it may be very difficult

Table 5. Influence of multiple Cultar™ (PP333) sprays in 1985 on spur quality of 'Red Prince Delicious'/M.26 apple trees.

		1985				1986			
Treatment	Rate g/ha	Bud dia. (mm)	Leaves/ spur	Leaf area/ spur (cm^2)	SLW (mg/cm^2)	Bud dia. (mm)	Leaves/ spur	Leaf area/ spur (cm^2)	SLW (mg/cm^2)
Check	—	2.8	6.4	71a**	8.8	2.9	6.3b	91b	10.0
PF, +2,+4	560	2.7	6.0	54b	8.6	2.9	7.4a	103b	9.9
PF+2,+4,+6,+8,+10	560	2.7	6.9	72a	8.1	3.2	7.5a	126a	10.4
PF+4,+6,+8,+10	560	2.6	6.4	69ab	8.5	3.1	7.3a	108ab	12.2
PF, +2,+4	280	2.8	7.0	58ab	9.0	2.9	6.6ab	86b	10.0*

*PF= Petal Fall, May 5, 1985; with subsequent sprays at 2-week intervals as indicated.
**Means within columns separated by Duncan's Multiple Range Test, 5% level.

Table 6. Influence of limb sprays of growth regulators (nontriazol compounds) on fruit set, size, and spur quality of spur-bound 'Starkrimson' apple trees.

		1985		Spur Quality 1984			Spur Quality 1985		
Treatment	Rate	Fruit/100 Clusters %	Avg. Fruit wt.(g)	Bud diam. (mm)	Leaves/ spur	Leaf Area/ spur (cm^2)	Bud dia. (mm)	Leaves/ spur	Leaf area/ spur (cm)
Check	—	39.8b*	107	3.3	7.4	100	2.3	7.9	82
Urea	2.64 g/l	57.8a	98	3.4	8.7	85	2.4	8.2	84
6 BA	50 ppm	41.2b	110	3.4	7.3	85	2.4	8.0	76
Alar	1500 ppm	59.1a	112	3.5	8.1	110	2.3	8.1	86
6 BA+Alar	50+1500 ppm	43.4ab	100	3.2	8.1	102	2.2	7.8	77
GA 4+7	10 ppm	52.7ab	105	3.3	8.2	85	2.5	7.8	92

*Means within columns separated by Duncan's Multiple Range Test, 5% level.

for general recommendations to be developed for commercial growers.

When all the methods of application in these studies are considered, banding soil sprays, broadcast soil sprays, trunk drenches and multiple foliar sprays were successful in causing growth reductions. The degree of growth reduction appeared greatest with the trunk drench and least with foliar sprays, although direct comparisons were difficult because of differences in rates applied.

In general, it appears that relatively low doses of these triazole growth regulators result in improved spur quality, however, the doses that improve spur quality resulted in limited or very short-term vegetative growth control. Growth control with these chemicals is variable within the tree and very dependent on method of application. The effects on yield and fruit quality were generally minimal in these studies with the greatest concern being the reduction in fruit length particularly at higher rates. Although these chemicals have promise for controlling tree size and reducing pruning, more research will be needed before predictable results can consistently be obtained.

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PERFORMANCE OF 'EMPIRE' ON DWARFING ROOTSTOCKS AND INTERSTEMS

D.C. Ferree and Bert L. Bishop[1]

INTRODUCTION

As growers move to more intensive orchard plantings, a continuing need exists for efficient dwarfing rootstocks. Although some field performance information is available with M.9 and M.26, both rootstocks have definite problems such as susceptibility to fireblight (8), lack of tolerance to slow internal soil drainage (2,6), incompatibility with certain cultivars (2,6) and requirement of physical support for the life of the orchard (5). Information on long-term performance of interstems is limited (5,7,11), but reports indicate they can be free-standing. The very dwarfing M.27 was a relatively recent introduction into the United States and it has not been widely tested either as a rootstock or interstem (13).

The trial reported here compares the performance of 'Empire', a new high quality, precocious and productive cultivar (15), on dwarfing rootstocks M.9, M.26 and M.27 and dwarfing interstems of M.9 and M.27 on both MM.106 and MM.111 rootstocks.

MATERIALS AND METHODS

In 1976, Dr. James N. Cummins of the New York State Agricultural Experiment Station at Geneva, NY, supplied one-year-old unfeathered 'Empire' apple trees to MA, NY and OH for a performance test. The following combinations were tested: trees on M.9, M.26, and M.27 rootstocks plus trees with 20 cm interstems of M.9 and M.27 on MM.106 and MM.111 rootstocks. Interstem trees were planted with the interstem/rootstock union slightly above soil surface. The trees were planted at a spacing of 3 x 5.5 m in a randomized block design with four replications with three trees of each rootstock or interstem in each replication. Trees of M.9, M.27 and M.26 were supported by a 1.25 m wooden post and all trees were trained as a central leader with minimal annual pruning. A 2 m wide herbicide strip with sod middles was maintained and pests were controlled by recommended practices.

Trunk circumference and yield/tree were recorded annually and in 1980 through 1987, fruit from each tree were graded on an FMC weight sizer and the number of fruit in each of the following diameter classes recorded: >8.0 cm; 8.0-7.2 cm; 7.1-5.5 cm, and <5.4 cm. The following three methods were utilized to examine cumulative tree efficiency: 1) cumulative yield/trunk cross-sectional area; 2) canopy efficiency=cumulative yield/(tree height x tree spread); 3) PIE (Pearce Improved Efficiency)=Yield/$(TCA)^{1.37}$ (12).

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RESULTS AND DISCUSSION

The trees had their first crop the third year (1978) after planting (Table 1). There was no difference in crop per tree in 1978 and 1979, however, in 1981 interstem trees on MM.106 tended to have the highest yields/tree, while trees on M.27 and M.27/MM.111 had the lowest. Trees on M.27 were significantly smaller than trees on the other rootstocks after the fourth growing season and this likely accounts for lower yields/tree on this rootstock. Although previous reports (1,9) have indicated that 'Empire' has a tendency to bear biennially, a review of the annual yields on the rootstocks in this study do not show this effect. Cumulative yields over the nine fruiting years show that 'Empire' trees on M.27 had lower yields than all other combinations. Interstem trees on MM.106 tended to have the highest yields and out-produced trees on MM.111 with M.9 and M.27 interstems. The greater productivity of interstem trees on MM.106 was also found by Lord *et al.* (10) in their MA planting which was a duplicate of the planting in OH. Similar to the findings in MA, there was no difference in yield between trees with interstems of M.9 or M.27 on the same rootstock.

Over the 11 years of this study, tree loss of all combinations was substantial, but could not be contributed to a single cause such as fireblight or collar rot. However, fewer trees on M.27/MM.111 were lost than on any other rootstock or interstem combination (Table 2). Lord *et al.* (10) and others (7,11) indicated that training 'Empire' to a central leader on these rootstocks was difficult. In this study, leader tended to crop heavily and lean and even with annual heading, it was not possible to sustain enough vegetative vigor to maintain a strong leader. This contributed to the small stature of all trees (Table 2). Harvest and pruning of 'Empire' trees could be handled entirely from the ground which was not possible with 10-year-old trees of other cultivars on interstems (4) or of trees on M.26 grown on this soil (3). Tree spread data indicated that trees on all rootstocks except M.27 had filled or slightly exceeded the allotted in-row space of 3 m. However, due to the tendency of 'Empire' to form numerous spurs and for the wood on trees grown on these rootstocks to bend under cropping, only minimum pruning was required and trees were easily contained at a 3 m spacing.

Calculations of the average bushels/acre produced over the last five years of the planting (using the 3.0 x 4.5 m spacing for all rootstocks except M.27 which was calculated at a spacing of 1.5 x 3.0 m) indicate that the interstems on MM.106 were most productive. Trees on M.27 had the lowest average yield even when spacing was adjusted to reflect actual

Table 1. Influence of apple dwarfing rootstocks and interstems on yield performance of 'Empire' apple trees.

	Yearly Empire Yield (lbs/tree)									Cum.Yld. /Tree
Stock	78	79	80	81	82	83	84	85	86	(lbs)
M.9	3.6	12.1	37.lb*	29.6ab	114.6ab	75.1abc	96.6a	112.6ab	87.6bc	569.1abc
M.9/MM.106	9.2	13.2	46.8ab	55.8a	142.7a	103.0ab	103.3a	136.7a	185.0a	796.1a
M.9/MM.111	2.8	12.4	33.8b	19.0b	69.7c	80.6abc	45.1bc	82.8b	114.2ab	464.0bc
M.26	6.9	15.7	37.9b	23.7b	79.1bc	55.3bcd	51.6bc	84.3b	105.4ab	460.0bc
M.27	3.4	7.6	16.9c	14.5b	23.0d	10.6d	15.0c	33.3c	15.0c	139.6d
M.27/MM.106	5.7	14.3	55.6a	55.0a	114.3ab	112.2a	78.8ab	108.5ab	148.6ab	693.2ab
M.27/MM.111	2.8	7.7	18.6c	10.2b	48.1cd	53.1cd	64.5ab	86.5b	108.2ab	400.0c
LSD 5%			15.7	26.3	41.2	45.2	40.6	45.2	82.5	255.4

*Mean separation in columns by Fisher's LSD 5%. Means from RCB experiment with 4 blocks and 7 rootstocks.

Table 2. Influence of apple dwarfing rootstocks and interstems on tree size and yield efficiency of 'Empire' apple trees.

					Tree Efficiency****			
	Tree Loss	Tree Size (m)		Trunk x-sect. Area(TCA)	Yield/ TCA	Canopy		Calc.*** avg bu/a
Stock	(%)	Height	Spread	(cm^2)	(lbs/cm^2)	Effic.*	PIE**	82-86
M.9	25	2.3ab****	3.4a	50.9c	13.7a	87bc	3.2a	560
M.9/MM.106	16	2.5a	3.6a	81.2ab	11.9a	106ab	2.4bc	772
M.9/MM.111	25	2.1b	3.4a	62.5bc	9.7b	80cd	2.1c	452
M.26	16	2.4ab	3.3a	60.0bc	9.3b	69cde	2.0bcd	432
M.27	16	1.5c	1.9b	18.4d	8.2bc	52e	2.9ab	422
M.27/MM.106	25	2.1b	3.4a	94.6a	9.1b	115a	1.7cd	648
M.27/MM.111	8	2.3ab	3.4a	59.4bc	6.9c	49e	1.5d	415
LSD 5%		.4	.2	26.9	2.0	21	.6	

*Canopy efficiencies=cumulative yield÷(Ht x Spread)
** PIE—Pearce Improved Efficiency=Yield÷($YCA^{1.37}$)
*** Average bushels/acre 1982-1986 calculated at the 3 x 4.5 (10' x 18') spacing for all rootstocks except M.27 which was calculated at 1.5 x 3.0 m (4.87' x 9.75') spacing.
**** Mean separation in columns by Fisher's LSD 5%.

Table 3. Influence of dwarfing rootstocks and interstems on fruit size distribution of 'Empire' apple trees.

	Percentage Distribution of Fruit Size (Diameter Classes cm)											
	1980			1981			1982			1983		
Stock	<8.0	8.0-7.3	7.3-5.7	<8.0	8.0-7.3	7.3-5.7	<8.0	8.0-7.3	7.3-5.7	<8.0	8.0-7.3	7.3-5.7
M.9	45ab*	44a	10	27abc	60	12c	17	28ab	54ab	10	32	46
M.9/MM.106	47ab	41ab	11	19bcd	47	21abc	16	33a	50abc	9	21	51
M.9/MM.111	45ab	41ab	12	13d	53	28ab	23	32a	44bc	4	18	63
M.26	35bc	45a	19	31ab	56	13bc	32	26b	42bc	6	27	49
M.27	28c	50a	21	22abcd	63	14bc	14	19b	65a	7	28	41
M.27/MM.106	54a	34b	11	35a	53	10c	37	29ab	33c	9	28	51
M.27/MM.111	33bc	49a	17	15bcd	52	32a	29	36a	33c	7	34	44
LSD 5%	14	10	10	13	19	15	17	9	19	6	13	14

*Mean separation in columns by Fisher's LSD 5%.

tree size. Possibly a different training system may be needed for trees on M.27 to equal the other rootstocks. It should be pointed out that these yields do not approach the 1000 bu/acre that most commercial producers strive to achieve. This is probably explained by the lack of dominance of the leader which prevented development of strong second and third tiers of fruiting scaffolds and by the annual chemical thinning which is required to achieve desirable fruit size. Trees on M.26 tended to have slightly larger trunk cross-sectional areas (TCA) than trees on M.9 or M.27, whereas MM.106 interstems were generally larger than MM.111 interstems on either stock. Trees on M.27 were significantly smaller than on the other rootstocks in height, spread and TCA.

Tree efficiency as evaluated by yield/TCA indicates that trees on M.9 and M.9/MM.106 were more efficient than all other combinations (Table 2). Trees on M.27/MM.111 were less efficient than when on M.27/MM.106 or either M.9 interstem combination. When Lord *et al.* (10) evaluated trees in their planting at eight years of age, they found no differences in yield/TCA. Evaluations of yield/TA and canopy efficiency suggested that both interstems on MM.111 were less efficient than those on MM.106, but the PIE evaluation indicated no difference. Van Oosten (14) expressed reservations about using yield/TCA to evaluate efficiencies of rootstocks based on Preston's (13) results demonstrating that trunk diameter and crown size were related in a different way for each rootstock. Hatton (9) also observed in some rootstock trials that crown size was sometimes smaller than reported from trunk diameter and he used the ratio of Kg yield to Kg wood. Van Oosten (14) suggested using the yield/crown volume as a desirable because it was not destructive and was useful in interpreting results for growers. Pearce (12) found a strong and reliable relationship between trunk circumference and tree weight, but found the calculations cumbersome. Since tree size of these trees were modified more than normal, cumulative efficiency was evaluated three ways (Table 2).

If Pearce (12) is correct and yield/(wt of tree) is the best measure of efficiency, then yield/TCA will be a mediocre estimate, but one made necessary by the difficulty of measuring tree weight. Yield/(wt. of tree) can be analyzed (without calculating the actual weights of trees) by applying Pearce's results as follows: Efficiency—yield/(wt. of tree) which is proportional to PIE=yield/$(TCA)^{1.37}$. It must be understood that the computed averages are relative measures and that the actual efficiency, in kilograms of yield divided by KG of tree weight, cannot be calculated without actually weighing trees. Yield/TCA can be seen as a compromise measure between yield alone and yield/(wt. of tree) as an estimate of tree efficiency. It is widely accepted and used and although PIE is likely closer to the actual definition of efficiency the conclusions reached by evaluating yield/TCA are similar. As suggested by Van Oosten (14) using the canopy dimensions in evaluating efficiency are also useful in the combinations such as M.27 and M.27/MM.111 that have excessive weak pendant wood and relatively low cumulative yields.

Since a potential problem with 'Empire' is a tendency of small fruit (10,15), one of the objectives of this study was to determine if any of these rootstocks would increase fruit size. Fruit size from this planting has been quite acceptable with an average of 22 percent of the fruit exceeding 8.0 cm (3 1/8 inch) diameter over the four years the fruit were graded (Table 3). It should be noted that these trees were chemically thinned on an annual basis over the last five years as they generally reflected a strong bloom and apparent excessive early set. Although with the year-to-year variation, it is difficult to select a clear trend, it appears that trees on M.27/MM.106 and M.9 tended to consistently have more fruit in the largest two fruit size classes than a number of the other combinations. It should be noted that 1983 was the second heavy crop in a row and none of the rootstock combinations was able to markedly improve size, while in the present study fruit from trees on M.27 were on the small side. Lord *et al.* (10) measured fruit size for three years from trees on the same rootstocks and found fruit from trees on M.27 to be larger in one year with no difference in the other years.

Lord *et al.* (10) monitored fruit quality over two years and reported that 'Empire' fruit from trees on M.27/MM.111 entered their climacteric later than those from trees on M.26 and M.27. Fruit from trees on M.9 and M.9/MM.106 showed the same characteristics in one of the two years, but the delay was small. No differences in fruit flesh firmness was detected. Soluble solids content of fruit from trees on M.27 was higher than that of fruit on M.26, M.9/MM.111 and M.27/MM.111. Senescent breakdown was more prevalent in fruit from trees on M.26 than on M.9, M.27, M.9/MM.111 and M.27/MM.111. Thus, according to the study of Lord *et al.* (10) these rootstocks can have minor influences on fruit maturity.

The 11 years of data from this trial indicate that MM.106 would be preferred over MM.111 as a rootstock for interstem trees because of slightly larger size, greater yield and yield efficiency. Interstem trees tended to be larger than trees on M.9 and similar in size to trees on M.26. Although Lord *et al.* (10) found M.9 and M.27 equally suitable as interstems, results from this study indicate that M.27/MM.111 resulted in a smaller, less productive and less efficient tree than on MM.106 and thus, M.27 would not be as desirable as M.9 as an interstem. A previous study (7), also with 'Empire' as a scion, suggested that M.9 was superior as an interstem to M.8. The trees on M.27 were very small with only average yield efficiency and it is difficult to envision such a rootstock having commercial potential for precocious cultivars such as 'Empire'. However, M.27 rootstock could have a place in very intensive plantings with cultivars such as 'Mutsu', which produce excessively vigorous growth on M.9 or M.26. It appears possible to maintain adequate fruit size on 'Empire' with annual chemical thinning, but this was likely achieved at some reduction in yield.

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POLYAMINES AS REGULATORS OF APPLE FRUIT DEVELOPMENT

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INTRODUCTION

Recently, a new group of naturally-occurring growth regulators, polyamines, have been implicated to play a role during fruit development. These compounds are anti-senescent and intimately associated with cell division in plants (3). In avocado, polyamine levels remained fairly constant during the cell division stage of fruit development, then declined rapidly at maturation (5). Additionally, in tomato, application of a polyamine inhibitor (DFMO) one day after pollination resulted in decreased fruit size, and this inhibition was reversed by polyamine application. It was postulated that reduced cell division and therefore, the reduction of harvestable fruit size was a result of low endogenous polyamines (1).

A study conducted in Italy by Costa and Bagni (2) indicated that a single foliar spray application of putrescine, spermidine or spermine to 'Ruby Spur' apple trees significantly and dramatically increased percent fruit set, number of fruit per tree at harvest and total yield. These authors reported that polyamine application had no effect on fruit size, shape, or quality.

In Ohio, application of these naturally-occurring compounds could have obvious potential value. Hence, this study was conducted to evaluate the use of polyamines for improving apple growth rate, harvestable yield, and quality.

MATERIALS AND METHODS

Plant Material and Treatment

Apple trees ('Golden Delicious') used for polyamine dip-application experiments were from a 30-year-old planting grown at Hort Unit 2 in Wooster. At full bloom, 15 trees (2 clusters/tree/treatment) were flagged and dipped in buffered solutions (pH=7) of selected polyamines. Dips were applied at one-week intervals for five weeks. Apple trees ('Lawspur', 'Redchief' and 'Smoothee') used for whole-tree polyamine spray application experiments were from a 6-year-old planting grown at the Mahoning branch station. At petal fall, buffered solutions of selected polyamines were applied to drip to five trees (1 treatment/tree) with a CO_2 sprayer. Apple trees ('Golden Delicious') used for polyamine inhibitor dip-application experiments were grown in 5-gallon pots in the Horticulture greenhouses at Wooster. At full bloom, flowers were hand-pollinated on two consecutive days and flagged. Each polyamine inhibitor was applied by dipping two flower clusters on eight trees into the appropriate buffered solutions at three-day intervals for four weeks.

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RESULTS AND DISCUSSION

Apple Growth and Endogenous Polyamine Levels

Apples exhibited a typical sigmoidal growth curve (Figure 1). The lag phase (0-28 days after pollination, DAP) corresponds to the cell division stage (4). During the log phase (28-120 DAP), cell division is reduced and cell enlargement occurs. Maturation and ripening occur during late log phase and the stationary phase (120-160 DAP).

All four major free polyamines (putrescine, cadaverine, spermidine, spermine) were detected in apple extracts. In general, polyamine titers were high early in apple development, then declined rapidly prior to enlargement, maturation and ripening (data to be published separately).

Polyamine Application and Apple Growth and Quality

Since high endogenous polyamine levels were associated with the cell division stage of apple development, it is reasonable that polyamine application may increase cell division during this time or extend the division stage. Both of these effects could result in larger harvestable fruit, more rapidly growing fruit, or fruit with altered quality because these parameters are, to a large extent, a function of the number of cells present within an apple (4). However, as shown (Table 1), multiple dip-applications of putrescine, cadaverine, spermidine, ornithine and arginine over a range of concentrations in 1985 had no effect on harvestable 'Golden Delicious' fruit size, shape or quality attributes. Spermine, on the other hand, caused premature drop at high concentrations and prevented further development of remaining fruit

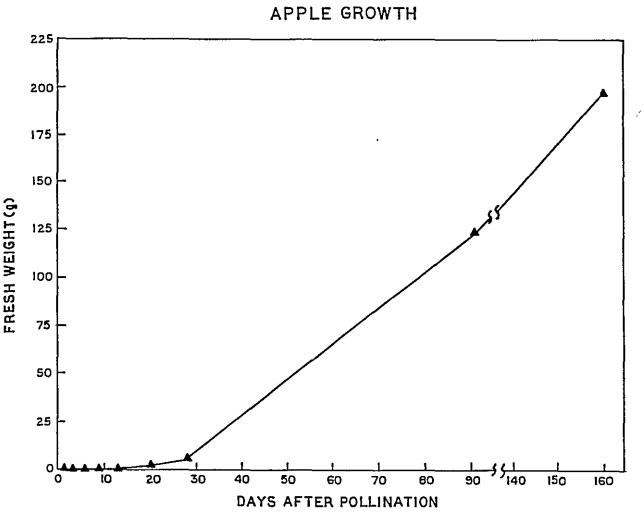

Figure 1. Fresh weight of 'Golden Delicious' apple fruit development. Each point represents the mean of at least 16 fruit. SEM is smaller than the symbol.

Table 1. Influence of multiple dip-applications of selected polyamines on firmness, color, russet, soluble solids, shape and mean harvest weight of 'Golden Delicious' apples during 1985.

Treatment	Conc. (mM)	Mean Fruit Weight(g)	Magness Taylor Firmness (kg/cm^2)	Color [a]	Russet [b]	Soluble Solids (°Brix)	Shape (length/ diameter)
Check	——	209[c]	3.90	4.46	2.97	13.9	0.86
Putrescine	0.1	186	3.85	4.67	2.54	13.1	0.87
	1	161	3.93	4.37	3.32	13.8	0.87
	10	196	4.04	4.41	3.45	14.5	0.85
Cadaverine	0.1	206	3.94	4.35	3.29	13.9	0.85
	1	187	4.06	4.35	3.04	13.3	0.87
	10	179	4.02	4.18	3.03	13.9	0.86
Spermidine	0.1	202	3.90	4.42	3.10	14.1	0.87
	1	173	3.81	4.59	3.13	13.6	0.86
	10	190	4.00	4.56	3.18	14.4	0.86
Ornithine	0.1	145	4.02	4.67	3.25	13.8	0.89
	1	203	3.99	4.50	2.98	14.3	0.87
	10	180	3.94	4.33	3.20	13.1	0.87
Arginine	0.1	211	3.91	4.66	3.18	13.8	0.87
	1	208	3.94	4.56	2.94	13.5	0.87
	10	190	3.98	4.50	3.02	13.7	0.87
LSD 0.05		NS	NS	NS	NS	NS	NS

[a] Color rated on a scale of 1 to 5. 1=yellow; 5=green.
[b] Russet rated on a scale of 1 to 5. 1=no russet; 5=completely russeted.
[c] Each value is the mean from a minimum of 15 fruit.

and adjacent leaves at lower levels. Additionally, these fruit and leaves were deformed (Figure 2). The following year, trees were given a single foliar spray of putrescine, spermidine and spermine at petal fall. 'Redchief' (Table 2), 'Lawspur' and 'Smoothee' (data not shown) did not respond to these applications with respect to percent fruit set, mean harvest fruit weight, total yield, or shape. Also, fruit growth rate was not affected (data not shown).

Collectively, these data suggest that developing apple fruit contain optimal endogenous levels of polyamines, and exogenous polyamines are unable to stimulate cell division or other positive changes in this organ. Moreover, these data are contrary to those of Costa and Bagni (2).

Polyamine Inhibitor Application and Apple Growth

Since developing apples may have optimal endogenous levels of polyamines, a more direct method to indicate a role for polyamines is through the use of biosynthetic inhibitors. DFMO and DFMA are two such compounds. However, multiple dip-applications of these compounds over a range of concentrations had no significant effect on fruit growth rate or harvestable apple size (Table 3). The inactivity of DFMO and DFMA was probably related to the impermeable nature of the apple skin to these compounds rather than an indication that polyamines play no role during apple development. No data exists to support or refute either hypothesis.

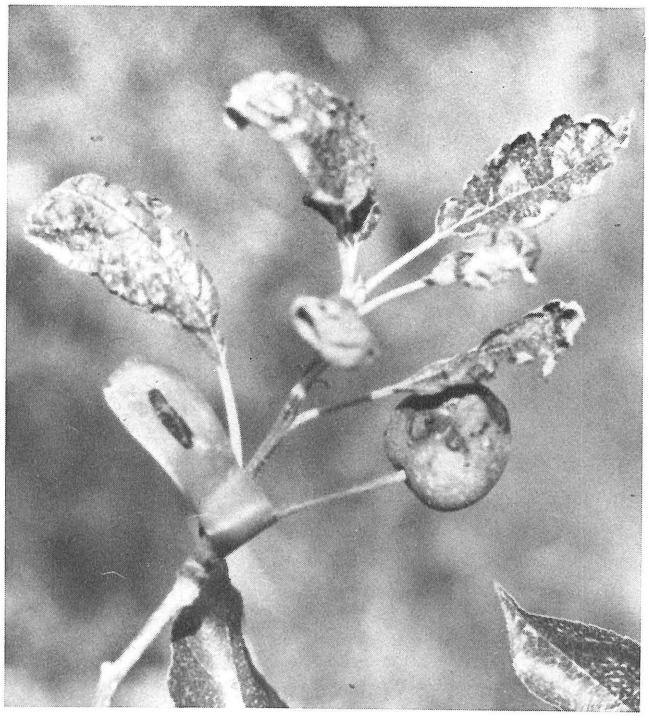

Figure 2. Deformation of apple fruit and supporting leaves treated with 1 mM spermine 0-28 days after pollination. Photograph was taken 16 days after pollination.

Table 2. Influence of a foliar spray of selected polyamines on fruit set, size, shape and yield of 'Redchief Delicious' apples during 1986.

Treatment	Concen. (mM)	Yield/ Tree (kg)	Avg. Fruit Weight (g)	Fruit Set (%)	Shape (length/ diameter)
Check		31.3 [a]	187	43.6	0.87
Putrescine	0.1	28.8	180	46.7	0.90
	0.01	34.9	183	51.4	0.88
	0.001	31.1	184	53.6	0.90
Spermidine	0.1	31.2	185	45.3	0.88
	0.01	35.4	180	47.9	0.88
	0.001	35.9	184	47.0	0.88
Spermine	0.1	29.9	183	46.6	0.86
	0.01	31.6	179	41.6	0.89
	0.001	33.8	180	48.6	0.87
LSD 0.05		NS	NS	NS	NS

[a] Each value is the mean from 5 replicate trees (5 fruit sampled/tree).

CONCLUSIONS

The major polyamines were present in high titer during the cell division stage of apple development. Hence, polyamines may be important for the normal growth and development of apples. However, polyamine and polyamine inhibitor applications do not indicate a physiological role for these compounds, and have no commercial importance at this time.

Table 3. Influence of multiple dip-applications of DEMO and DEMA on fruit diameter in May, June and August and harvest weight on 'Golden Delicious' apples during 1987.

Treatment	Fruit Diameter (cm) 5/15	6/30	8/3	Mean Harvest Weight (g)
Check	3.17[b]	5.93	7.26	194
10 mMDFMO	3.29	6.19	7.15	219
1 mM DFMO	3.08	5.83	7.56	192
10 mM DFMA	3.25	6.14	7.44	214
1 mM DFMA	3.16	6.00	7.12	187
LSD 0.05	NS	NS	NS	NS

[a] DFMO=difluoromethylornithine; DFMA=difluoromethylarginine.
[b] Each value is the mean from 8 replicate trees (2 fruit/tree/treatment).

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Comparing Regional Cost of Production for Strawberries

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INTRODUCTION

Between the years of 1980 and 1986, production of fresh market and processing strawberries in the United States increased by 52.4 percent (482 millions pounds to 734 million pounds) for fresh and 29.5 percent (220 million pounds to 284 million pounds) for processing. The value of fresh and processing berries increased 83 percent ($231 million to $423 million) for fresh and 40 percent ($57 million to $81 million) for processing (1). In terms of supply, California produced an average of 75 percent of the fresh and 72 percent of the processing tonnage during this period, while Ohio produced only 1.5 percent of the fresh and none of the processing tonnage.

Given the growth in demand for fresh and processed strawberries, Ohio producers need to examine their competitive position relative to California in supplying fruit to consumers and processors. By investing in new variety development, improved cultural management, and/or market development, Ohio producers may be able to increase its share of the fresh and processing markets. As a first step in this process, growers need information on the relative cost of producing strawberries both in Ohio and California. Attention can then be focused on those growing, harvesting, or marketing activities which will have the greatest impact on cost per pound and thus improve Ohio's competitiveness in the fresh and processing markets.

PROCEDURES

Standard budgeting techniques were utilized in determining the costs of production for Ohio and California. Previously published data (2,3,4) was utilized as initial budget outlines, but modifications were made in order to develop a common budget format. Cultural activities used in this study are consistent with those of the previous studies and were separated into establishment, preharvest, harvest, or postharvest categories based upon when the activities occurred during the production of the crop. Within each category, costs were identified as materials, equipment, or labor. Establishment costs in Ohio were prorated over three harvesting seasons. In California, a new crop was assumed to be planted each year.

Sensitivity analyses were used to determine the impact on cost per pound for fresh strawberries in Ohio as a result of changing: yield, management wage, hired labor wage, interest rate, and level of capital investment. Additional analysis was performed in order to determine the amount of change which must occur in each of the above variables in order to reduce the production cost per pound for fresh berries by $0.01.

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RESULTS AND DISCUSSION

A summary of the expected production expenses for fresh and processing strawberries is presented in Table 1 for Ohio and California. Results indicate that total production costs per acre (assuming a yield of 11,000 pounds in Ohio and 60,000 pounds in California) are $6,385 in Ohio and $28,185 in California. Assuming a mix of 75 percent fresh and 25 percent freezer, the resulting cost per pound for fresh berries in Ohio is $0.605 and $0.495 in California. If Ohio producers are to break-even on fresh market berries selling for $0.61 per pound, then a yield of 11,000 pounds per acre is the target. Recognizing that the state average for strawberry yields had been around 8,000 pounds per acre, growers need to focus their attention on cultural activities and capital investments (such as irrigation equipment for frost protection) which will increase yields.

In terms of overall costs, harvesting expenses account for the largest percentage of total costs, 44.6 percent in Ohio ($2,851/$6,385) and 51.8 percent in California ($14,600/$28,185). Within harvesting, labor accounts for 84.7 percent of the total in Ohio and 83.2 percent in California. As labor availability continues to decrease and labor wages increase, new practices will need to be implemented which will increase the efficiency of labor used to harvest strawberries.

Following the development of the production budgets, sensitivity analysis was used to examine how changes in variables such as yield, wage rate, interest rate, and level of capital investment affect fresh cost per pound, Table 2. Given the current value for each variable, the amount of change required to reduce the cost per pound by $0.01 for fresh (or processing) berries in Ohio is presented in actual units and as a percentage of the current value. Thus, an increase in per acre yield of 400 pounds or 3.6 percent is required to reduce the cost per pound by $0.01. Likewise, a decrease in the per hour management wage (wage plus benefits) of $0.98 is required.

The information in Table 2 should provide growers with some useful information. First, no single variable has to be targeted to bear the full load of reducing costs. This can be spread among all variables. Second, while interest rates may be controllable for a single individual, growers still have the freedom to shop among lenders or refinance loans as economic conditions change. Third, while wage rates can be decreased in order to save money, efficiency of labor is also an issue. By examining the cost per unit of output produced, a grower can evaluate whether higher wage offers attract more efficient workers. Finally, yield increases are the surest way to improve profitability. By matching cultivars with cultural practices and environmental conditions, growers in Ohio should be able to provide a high quality product to fresh market and processing buyers at a competitive price.

Table 1. Summary of production expenses for fresh and processing strawberries in Ohio and California

ITEM	OHIO TOTAL COST/A.	OHIO FRESH COST/LB.	OHIO FREEZER COST/LB.	CALIFORNIA TOTAL COST/A.	CALIFORNIA FRESH COST/LB.	CALIFORNIA FREEZER COST/LB.
ESTABLISHMENT COSTS:						
MATERIALS	$756	$0.069	$0.069	$1,480	$0.025	$0.025
EQUIPMENT	85	0.008	0.008	1,089	0.018	0.018
LABOR	853	0.078	0.078	2,361	0.039	0.039
TOTAL ESTABLISHMENT COSTS	$1,695	$0.154	$0.154	$4,930	$0.082	$0.082
PREHARVEST COSTS:						
MATERIALS	$173	$0.016	$0.016	$500	$0.008	$0.008
EQUIPMENT	65	0.006	0.006	563	0.009	0.009
LABOR	346	0.031	0.031	1,217	0.020	0.020
TOTAL PREHARVEST COSTS	$584	$0.053	$0.053	$2,280	$0.038	$0.038
HARVEST COSTS: (Yield in Pounds)	11000	8250	2750	60000	45000	15000
(Percentage of Crop)		75%	25%		75%	25%
MATERIALS	$413	$0.050	$0.000	$2,277	$0.050	$0.001
EQUIPMENT	23	0.002	0.002	180	0.003	0.003
LABOR	2,416	0.229	0.191	12,142	0.213	0.170
TOTAL HARVEST COSTS	$2,851	$0.281	$0.194	$14,600	$0.267	$0.173
POSTHARVEST COSTS:						
MATERIALS	$273	$0.025	$0.025			
EQUIPMENT	36	0.003	0.003			
LABOR	210	0.019	0.019			
TOTAL POSTHARVEST COSTS	$519	$0.047	$0.047			
TOTAL VARIABLE COSTS	$3,954	$0.381	$0.294	$16,880	$0.305	$0.211
INTEREST ON OPERATING CAPITAL	$395	$0.038	$0.029	$1,688	$0.030	$0.021
ALLOCATED FIXED COSTS	$1,031	$0.094	$0.094	$3,035	$0.051	$0.051
PROPRATED ESTABLISHMENT COSTS	$1,005	$0.091	$0.091	$6,582	$0.110	$0.110
PRODUCTION COSTS	$6,385	$0.605	$0.508	$28,185	$0.495	$0.393
RETURNS:						
SALES	$6,386	$0.610	$0.492	$30,315	$0.590	$0.251
RETURN OVER VARIABLE COSTS	$2,036	$0.191	$0.169	$11,747	$0.255	$0.018
RETURN OVER PRODUCTION COSTS	$1	$0.005	($0.016)	$2,130	$0.095	($0.142)

Table 2. Current value and amount of change required in yield, wage rate, interest rate, or level of capital investment in order to reduce the estimated cost of producing fresh strawberries in Ohio by $.01 per pound.

Variable	Current Value	Change	Percent Change
Yield (lbs/A.)	11,000	400	3.6
Management Wage ($/hr)	9.50	-0.98	-10.3
Hired Wage (H/hr)	7.20	-1.49	-20.7
Interest Rate (%)	10	-2.6	-26.0
Capital Investment ($)	3,647	-1569	-43.0

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EFFECTS OF WHITE PAINT ON TRUNKS OF GREENHOUSE-GROWN APPLE TREES

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INTRODUCTION

Painting tree trunks white has been recommended as a practice to reduce winter freeze damage to fruit trees (1,7,8). Winter injury appears as vertical splits in the lower trunk through the bark and cambium exposing the wood. The consequences of this damage are the infestation of rot and canker organisms, which may have a serious debilitating or lethal effect on the tree.

One reason for this kind of winter injury is the sudden drop in temperature at night following a particularly sunny day (1,6,8). As soon as the sun sets, great temperature differences exist across the trunk with the highest temperatures on the southwest side (1,4,5,8). Jensen *et al.* (3) has shown that the temperature gradient across the trunk is greatest in winter because, in summer, shade from the leaves moderate the effect of radiant energy. Reflection from snow increases the severity of these problems (1). Trees with reddish brown thin bark (e.g., peach) are especially susceptible to winter injury (1,5,6).

White paint applied to the south and southwest sides of the tree trunks can maintain an 8-16°C cooler cambium temperature on exposed sides of the trunk on sunny winter days in comparison with unpainted check trees (1,3,4,8), thus reducing temperature variations in the tree trunk. Non-painted trees reflect about 15 percent of the sunlight that strikes the trunk the rest of the sunlight energy will be absorbed rapidly and cause increased temperature of trunk tissues (9).

To be desirable for painting tree trunks, paints must be easy to apply, be durable, not flake off with the growth of the trunk, and reflect sunlight. Ritter *et al.* (9) advises that paints be free of phytotoxic oils or driers, which can injure trees. It is necessary to have as low an oil content in the paint as possible (6). Good quality indoor white latex paint applied to the tree trunk is the most practical in preventing winter sunscald injury (4,5,9). Some latex paints cause injury in silver and sugar maples (5). Stone and Frederick (10) observed necrosis in cambial tissues and cankers and stem swelling resulting from callus formation following application of aerosol tree and log marking paint in sugar maple. The bark tissues on rapidly growing trees of this species apparently provide little resistance to penetration of toxic substances to the cambial region.

Recently a new polyvinyl butyral paint (Tree Max^{TM}) has been advertised as having improved permeability to O_2,CO_2, and water vapor and to be particularly desirable as a trunk paint to help prevent winter damage. As the acrylic content of normal latex paint increases, permeability decreases. To determine the influence of the new paint with paints of differing permeability on net photosynthesis and transpiration, a study was initiated on some young greenhouse apple trees.

MATERIALS AND METHODS

One-year-old MM.106 apple trees were trained to a single shoot and grown in a media of soil, sphagnum peat moss and perlite (1:1:2) in 30 x 30 x 30 cm containers. Temperatures in the greenhouse were 70°F day and 60°F night; and the trees received additional light from HID lamps suspended from above from 10:00 p.m. until 2:00 a.m. The bottom one-meter of the trunk (approximately 50-60 percent of total) was painted with the leaves still attached, taking care to thoroughly coat the bark of the entire tree, but not the lateral buds in the leaf axils.

In October 1986, the following paints all with titanium oxide as the whitener, were applied: 1) Tree Max^{TM}, polyvinyl butyral; 2) 10.7 percent acrylic/ 52.2 percent water; 3) 16 percent acrylic/81.2 percent water; 4) 24 percent acrylic/72 percent water; 5) 26 percent acrylic/34 percent mineral spirits; and 6) control, unpainted. The treatments were arranged in a randomized block design on the greenhouse bench with five single tree replications. Photosynthesis and transpiration of the first three leaves above the paint were measured two and eight days after painting, with an ADC portable infrared gas analysis system. Readings were taken at light levels above 800 $\mu Em^{-2}s^{-1}$, which is accepted as the saturating intensity for apple. After the last reading, bark tissues were removed, fixed and stained by the technique described by Cross and Moorhead (2). Tissues were examined under both the light microscopy and scanning electron microscope to detect possible cell damage (Figure 1). Tissues were also examined by the energy dispersive X-ray analyzer.

RESULTS AND DISCUSSION

No visual phytotoxicity symptoms appeared from any of the treatments and growth was not affected (data not presented). Photosynthesis and transpiration of the first fully expanded leaf above the painted bark were not influenced by the treatments (Table 1). No cell damage could be detected under the light microscope. Titanium (Ti) is not present in large amounts in apple tissues. The X-ray analysis revealed that Ti cations were present in the paint layer at a 91.6 percent frequency in relation to Al, K and Ca ions, and that the presence of Ti dropped to 26.6 percent in the bark and 0 percent in the cells below the bark (Figure 2). Since the paint with mineral spirits which was anticipated to cause the most penetration and injury resulted in no penetration of Ti, it would appear that none of the paints in this study penetrated beyond the bark tissues.

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TABLE 1. Influence of selected white paints on photosynthesis and transpiration of greenhouse-grown MM.106 apple trees.

Paint	Photosynthesis mg $CO_2 dm^2 hr^{-1}$ Days After Painting		Transpiration g $H^2O dm^{-2} hr^{-1}$ Days After Painting	
Characteristics	2	8	2	8
Polyvinyl butyral (Tree Max TM)	10.0	13.3	2.2	2.8
10.7% acrylic/52% water	12.9	14.9	2.7	3.2
16% acrylic/81.2% water	9.6	15.6	2.4	3.0
24% acrylic/72% water	8.9	15.3	2.3	3.1
26% acrylic/34% mineral spirits	9.9	15.7	2.2	2.9
Control, untreated	10.3	14.9	2.3	3.0

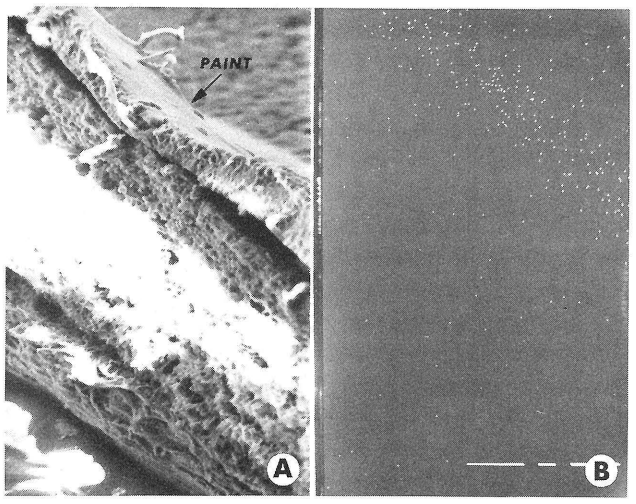

Figure 2. A. Tissue of tree trunk with paint (26% acrylic and 34% mineral spirits) on the bark under the electron microscope (220X). B. Distributuionof Ti elements from the paint (right corner) through the tissue to show if the paint penetrates bark.

Although the permeability of the paints with various levels of acrylic was not directly tested in this study, the reported increased permeability of the polyvinyl butyral (Tree Max^{TM}) paint gave no advantage in rates of photosynthesis or transpiration over paints ranging from 10.7 percent to 26 percent acrylic. It appeared that the paints remained in and on the bark and the basic physiological processes of the trees were unaffected. The results may have been influenced by the method of application, coating only bark tissue and leaving the lower leaves attached. Since these trees were actively growing at the time of application and the bark of greenhouse trees likely would be more tender than field grown trees, it was decided not to remove leaves and paint over the fresh leaf scars, which would provide direct access of the paint to interior tissues.

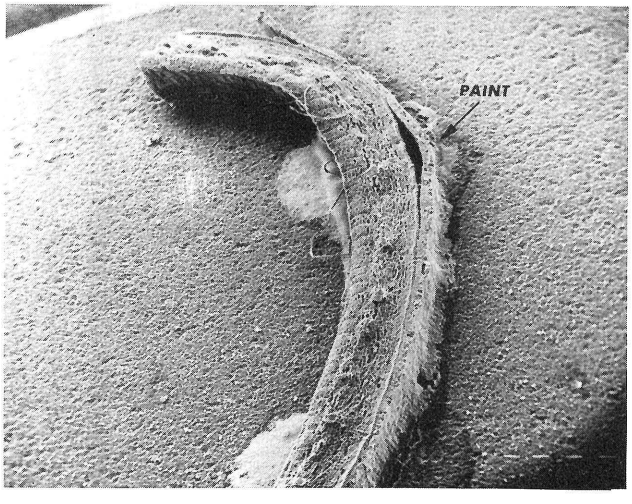

Figure 1. Tissue of tree trunk with paint (34% mineral spirits) on the bark under the electron microscope (60X).

It was surprising that the oil-based paint in this trial did not result in any phytotoxicity or affect photosynthesis or transpiration. It is obvious from Figure 2 that this paint was confined to the surface and bark tissues. Reports from others (4,6,9) indicate that oil-based paints should be avoided and the authors consider this prudent because under field conditions cracks or other openings that would allow penetration of toxic materials to living tissue would likely be present. It also should be pointed out that physiological measurements were taken relatively soon after paint application. However, no visual phytotoxicity appeared on the trees eight weeks after treatment when the trees were discarded.

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CYTOKININ INJECTIONS ARE INEFFECTIVE IN OVERCOMING THE RESPONSE OF YOUNG APPLE TREES TO ROOT PRUNING

James R. Schupp and David C. Ferree[1]

INTRODUCTION

Root pruning reduces shoot elongation, leaf size, net photosynthesis (Pn) and transpiration (Tr) of young apple trees (2,9). The root system is a primary source of cytokinins for the whole plant (14) and cytokinins move upward in the xylem (3,4,11) to the shoots where they regulate shoot growth (4,7) and Pn (1). This study was initiated to determine whether exogenous cytokinins administered by xylem injection could counteract the reductions of shoot growth, leaf size, Pn and Tr of young apple trees induced by root pruning.

MATERIALS AND METHODS

In 1985, one-year-old 'Red Haralson'/M.7 apple trees were planted in the center of 30 cm x 30 cm x 30 cm containers in a medium of 1:2:1 soil, perlite and peat by volume. The trees were headed 5 cm above the graft union and trained to a single shoot. Each container received 30 g of 14N:6.1P:11.7K osmocote slow-release fertilizer and the trees received water and pesticides as needed. Twenty-four trees were selected for uniformity and assigned treatments as follows:

Treatment	Root Pruning	Cytokinin Injection
1	0	None
2	0	Zeatin
3	0	Benzyladenine
4	1	None
5	1	Zeatin
6	1	Benzyladenine

The treatments were arranged as a randomized complete block design with eight single tree replications. Root pruning was applied 50 days after shoot growth began by making a vertical cut with a metal blade on two sides of the stem at a distance of 5 cm from the stem. Immediately after root pruning, the cytokinins were pressure injected, using the technique described by Sterrett and Creager (12). A 2 mm diameter hole was drilled into the one-year-old scion stem just above the graft union and 1 ml of 200 ppm Zeatin (Z) or 6-benzyladenine (BA) was forced into the hole using a modified vise-grip plier equipped with a stainless steel injector barrel and a disposable plastic syringe. Control trees received a 1 ml injection of 12 percent ethanol carrier solution instead of a cytokinin. To determine the distance that the solutions could be forced into the stems, several similar trees were injected with 1 ml of 0.4 mg/ml saffranin dye solution. Shoot length was measured at 7-day intervals. Size of the newly expanded leaves was measured at 21 days after root pruning with a Li-Cor LI-3000 leaf area meter. Pn and Tr of the 10th fully expanded leaf on trees in the first four replications were measured at three and 10 days following treatment. Pn was determined with a MSA Model 200 infrared gas analyzer using the technique described by Sharma (10). The leaves were placed in a clear plexiglass leaf chamber and illuminated with a saturating PPFD level of 900 μmol $M^{-2}Sec^{-1}$ emitted from Sylvania phosphorus-coated metal-arc lamps. Transpiration was measured with an EG and G International Model 800 dew point hygrometer.

RESULTS AND DISCUSSION

Saffranin dye injected into similar trees revealed that the injection moved upward in the xylem for a distance of 20 to 25 cm and downward from the injection point approximately 10 cm (data not presented). These patterns of dye movement are in close agreement with those reported for several fruit species, as determined by Sterrett and Creager (12).

Reduced shoot length was apparent on root pruned trees 21 days after the treatments were applied, however cytokinin injections had no effect (Table 1). Similarly, size of newly

Table 1. Effect of root pruning and cytokinin injection on shoot length and size of newly expanded leaves of greenhouse-grown 'Red Haralson'/M.7 apple trees, 21 days after treatment.

Root Pruning	Cytokinin	Total Shoot Length (cm)	Leaf Size (cm^2)
Unpruned	0	80.0	30.4
	Z[z]	80.9	31.1
	BA[y]	79.2	28.7
Pruned	0	74.5	26.0
	Z[z]	74.4	25.3
	BA[y]	70.2	25.5
Main Effects			
Root Pruning		*	*
Cytokinin		NS	NS
Interaction		NS	NS

*Significant at the 5% level

[z]1 ml of 200 ppm Zeatin

[y]1 ml of 200 ppm 6-benzyladenine

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expanded leaves was reduced by root pruning, but cytokinin injections had no effect (Table 1). Total growth of the trees in this experiment was less than that of trees in previous greenhouse studies (2,9). This study was initiated in July, while previous greenhouse work began in April or May, thus the trees in this study had been dormant in cold storage for an additional two to three months and were grown in more stressful high temperatures than those used previously. Additionally, the trees in this study had been infested with thrips [*Heliothrips haemorroidalis* (Bouche)], which reduced tree vigor, deformed the leaves, and delayed the application of treatment until the insects were brought under control with insecticide sprays.

Our results agree with those of Miller (5), who found no effect on terminal growth of young apple trees with 500 ppm injections of BA, and with Wang and Rom (15), who recently reported no effect on apple leaf size with foliar applications of BA.

In agreement with previous work (2,9) root pruning reduced Pn and Tr three days after treatment, but differences were not significant after 10 days (Table 2). Cytokinin injections had no effect on Pn or Tr. Similarly, recent work at Washington State University (6) reported that foliar-applied exogenous cytokinins also had no effect on Pn or Tr of root pruned apple trees, although BA is effective in restoring Pn of root pruned bean (1).

This study was initiated to determine if exogenous cytokinins injected into the xylem could counteract the effects of root pruning on vegetative growth, Pn and Tr of young apple trees by replacing the endogenous cytokinins, which are reduced by root pruning (8). The concentration of exogenous cytokinins used was within the range which causes lateral bud break (5,13) and far in excess of that which occurs naturally (3,4). The injection technique has previously been shown to be an effective method of delivering growth regulators to the growing points of young apple trees (5,13).

The injections of either Z or BA caused no measurable effect on shoot elongation, leaf size, Pn or Tr, making any conclusion as to the role of cytokinin in the root pruning response of apple impossible. Stem injected Z or BA were not effective in overcoming the growth inhibition of root pruned apple trees.

Table 2. Effect of root pruning and cytokinin injection on photosynthesis and transpiration of leaves of greenhouse-grown 'Red Haralson'/M.7 apple trees.

		Days After Treatment			
		3		10	
Root Pruning	Cytokinin	Pn[z]	Tr[y]	Pn	Tr
Unpruned	0	16.6	2.1	16.8	2.0
	Z[x]	16.2	2.0	14.8	2.1
	BA[w]	15.4	1.7	15.9	2.0
Pruned	0	13.0	1.6	14.2	1.7
	Z[x]	11.7	1.4	13.3	1.7
	BA[w]	12.7	1.5	14.7	1.7
Main Effects					
Root Pruning		*	*	NS	NS
Cytokinin		NS	NS	NS	NS
Interaction		NS	NS	NS	NS

*Significant at the 5% level.

[z]Pn=$mgCO_2dm^{-2}hr^{-1}$

[y]Tr=$gH_2Odm^{-2}hr^{-1}$

[x]1 ml of 200 ppm Zeatin

[w]1 ml of 200 ppm 6-benzyladenine

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ORCHARD GEOMETRY AND PESTICIDE DEPOSITION EFFICIENCY

Franklin R. Hall[1], David C. Ferree[2], Donald L. Reichard[3] and Harvey R. Krueger[4]

INTRODUCTION

Increased concern about pesticide pollution, development of pest resistance, more expensive pesticides, recent advances in low volume spraying, and integrated pest management make it extremely important that we apply the correct amount of pesticide on the foliar target. Lack of precise pesticide recommendations can result in pesticide applications that are more costly, monetarily and environmentally, than they should be. Application techniques, pesticides, and orchard systems have changed, but the concepts of calibration, equipment, and spraying efficiency have not kept pace. The crop sprayer today is basically the same as it was 30 years ago — liquid container, pump, and nozzles. However, the chemicals have changed dramatically, with increases in efficiency of up to 20-fold over the standards of just 10 years ago.

Another problem is that the fruit industry in the U.S. is in the midst of dramatic changes in the size and number of trees grown per acre. For example, the 1976 Ohio fruit tree survey indicates 25 percent fewer acres planted to apple but 18 percent more trees than shown in the 1968 survey. A change from standard to semi-dwarf and dwarf trees has resulted in an increased Ohio apple tree density since 1968 from an average of 40 to 63 trees per acre — a 58 percent increase. Also, changes in varieties as well as in rootstocks have resulted in alteration of foliage and branch configuration within the trees. These trends also have been observed in most other fruit growing states. High density orchards combined with the development of low volume spray equipment and a lack of change in the development of recommendations and product labels have contributed to grower confusion about pesticide rates and specific spray volumes for various orchards.

One of our recent studies involved adjustments of pesticide rates/volumes according to the type of planting. As we increase the proportion of high-density orchards by means of dwarfing rootstocks, it makes sense to ask..."Do we need the same amount of material per acre as in our standard plantings"? This report is the result of an on-going program designed to increase the precision of pesticide application in orchards.

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MATERIALS AND METHODS

Apple plantings located at OARDC, Wooster were used for all experiments (Table 1). "Sprayer configurations" and "orchards used" for each experiment are listed in Table 2. For foliar samples in the North, M.9 and M.26 plantings, four to six trees, as similar as possible were selected from each system. Sample sites were foliage, approximatly 3' square with centers at approximately 4 to 6' high on each tree on the side nearest the sprayer. Shortly after spraying (when residues had dried), 50 leaf discs (approximately 1/2" in diameter) were sampled from each site in each tree and analyzed for insecticide residues according to methods previously reported (1). Residues of azinphosmethyl (Guthion 50 WP) used at 1 lb/100 gallon (1.19 gm/l) and carbaryl (Sevin 50 WP) used at 2 lb/100 gallon, 2.4 gm/l) were analyzed according to standard toxicological practices (1).

Handgun applications (to drip) were also made with a truck-mounted Myers sprayer operating at 500 psi (D-10 nozzle) to the North, M.9 and M.26 systems. Individual trees were sprayed by walking around each tree with the hose and gun until all foliage was wet to drip.

Table 1. Orchard parameters of tree density and row footage/acre.

Orchard	Planting Distance (ft)	Trees/Acre	Length of row per acre (ft)
North	30 x 30	48	1450
M9	10 x 18	242	2420
M26	12 x 20	181	2180
Pyramid	14 x 18	172	2420
Interstem	9 x 15	322	2900
Trellis	8 x 12	452	3630
Slender Spindle	5 x 10	871	4360

Table 2. Orchard and sprayer configurations.

Orchard	Sprayer	Gallons/acre	Travel (mph)
North	Myers 2A36[a]	130	3.0
M9 "	2A36	96	2.5
M26 "	2A36	112	2.5
High Density	Myers Mity-Mist[b]	209	2.5

[a]Engine driven, trailed air blast sprayer; 500 gallon tank.
[b]PTO driven air blast sprayer; 100 gallon tank.

In the high density apple systems, (Pyramid, Interstem, Trellis, and Slender Spindle), a spray of permethrin (Ambush 2E) at a concentration of 3.3ml/l was applied by a low-volume PTO Myers sprayer (Mity-Mist) at 6.88 l/minute. All nozzles were redirected to cover spray target areas for each system. Spray deposits were collected on glass slides at the same six locations/tree (eight replicate trees of each system) and residues were analyzed (2).

Methods used in previous studies (2) with apple tree high density blocks were utilized in peach tree blocks to determine spray capture efficiencies. Peach trees were trained to three different tree shapes: natural, vase and fan. All were planted at 10 x 15' distances and mechanically hedged to a height of 8'. All systems were sprayed from one side of the tree with a fluorescent tracer (Rhodamine B with extra S) in 50 gallons/acre (GPA) with the Mity-Mist sprayer. Deposits were captured on glass slides located on the other side of the respective canopies at 8' heights. Tracer deposits were then quantified with a fluorometer (Turner Model 110).

Percent canopy densities were obtained by taking black and white, 35 mm, fish-eye pictures at ground level and aimed towards the sky at midday within each apple high density orchard system. Canopy densities were estimated by use of image analysis (Dapple Systems) as described by Hall et al. (3).

RESULTS

Our previous studies (2) had shown that high density systems differ in spray capture efficiency (Figure 1), which reflects the differences in canopy volume, leaf area, and the amount of light interception by these canopies. Average spray deposits were highest in the trellis trees, followed by slender spindle, interstem and pyramid hedgerow tree systems. An evaluation of culled fruit from each of these systems indicated almost no cullage due to insect or disease damage. This is of interest since the trellis and slender spindle trees had five to six times more spray deposit than the pyramid hedgerow trees in this experiment. The amount of spray volume and resulting deposition delivered to the pyramid system approximates the amounts used successfully to protect the system on a commercial basis. Thus, the increase in spray deposits within the other systems represents not only economic waste but an unnecessary environmental entry and may also contribute to pest resistance phenomena. Additionally, the data in Table 3 indicate the significant changes that take place in foliar density (and hence spray deposition efficiency) from bloom to the cessation of terminal growth in July. This too represents another potential opportunity for adjustment in the application technique, i.e., faster travel speeds in the spring and slower travel speeds in mid-season when foliage density is at a peak.

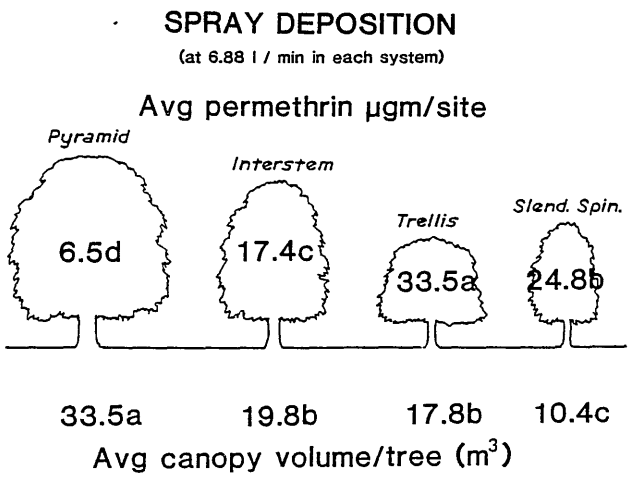

Figure 1. Spray deposition efficiencies in apple orchard management systems. Means followed the same letter across each system are not significantly different at P=.05 level (DNMRT).

Table 3. Seasonal changes in foliar target density.

	Mean % Canopy Density[1]	
Orchard System	May 9	Jul 13
Pyramid Hedgerow	59.6 a	89.6 a
Interstem	46.0 b	80.0 ab
Trellis	41.2 b	69.7 b
Slender Spindle	46.7 b	87.7 a

[1]Means in each column followed by same letter are not significantly different at P=.05 level (DNMRT). Arcsine transformations were made prior to analysis.

Unless the pesticide delivery rates per foot of travel are adjusted, the more dense plantings (having a greater row footage on a per acre basis (Table 1)) automatically will receive a higher spray volume and hence higher amounts of pesticide per acre. The easiest adjustment for growers to make is a change in speed of travel within the different blocks. Thus in a subsequent experiment, we adjusted the spray gallonage to 50 GPA for planting to account for this difference in row spacings and row footage. If there were no differences in tree canopy interception of sprays, then our deposition values should be approximately the same for each system. While we still received higher deposits on the trellis system (Table 4), there was clearly a closer agreement in pesticide deposits between the systems as a result of the adjustments for each planting.

A comparison of handgun vs. airblast deposition values showed that handgun deposition (at dilute) was more consistent than that of the 2A36 at 3X in placing a finite pesticide level on the various foliar surfaces (Table 5). This may be a reflection of the handgun operator's ability to correctly judge and correct for the coverage the tree is receiving during the application. Clearly, the 2A36 deposition levels were not as consistent between tree systems. This again reflects the differences between canopy architecture in the systems as noted in Figure 1. This problem is exactly what was defined in a review by Hall (4) in an atempt to illustrate the need for orchard adjustments according to estimates of foliar volume. While there was a trend towards higher deposition in the M26 vs. the larger North trees (handgun), it did not match the

significant increases (148%) acheived with the 2A36 (Table 5). Again, unless predetermined adjustments are made on the speed of travel and other factors to account for reduced tree size, increased row footage, tree capture efficiency because of cultivar or pruning practices, etc., there is likely to be increased pesticide deposition in the higher tree density plantings.

Table 4. Deposition from adjusted spray delivery rates to account for differences in row spacings/row footage[1].

Orchard System	Avg μg carbaryl/site	Avg % canopy density
Pyramid Hedgerow	459 a	75 bc
Interstem	565 ab	68 ab
Trellis	680 b	64 a
Slender Spindle	415 a	78 c

[1]Means in each column followed by same letter are not significantly different at P=.05 level (DNMRT). Arcsine transformations were made on % data prior to analysis.

Table 5. Pesticide deposition — handgun vs. airblast sprayer.

	Avg μg azinphosmethyl/50 leaf discs[1]	
Orchard	Handgun	2A36
North	210	256
M.9	223 (+6)	367 (+ 43)
M.26	227 (+32)	636 (+148)

[1]Collection from sites on N,E,S, and W sides of trees. Fgures in ( ) represent % change from baseline values in North orchard for each application system.

Table 6 shows a similar trend while at the same time clearly differentiating "in row" vs. "sprayer side" spray deposits. It is this difference which allows the use of alternate row techniques (ART), e.g., the lower dosed areas of the tree canopy leave places (refugia) for survival of predators. The data in Table 6 also indicate the problems that large canopies present when attempting to establish "even coverage" in orchard plantings.

Measurements of potential spray drift or off-target placement within these same blocks are presented in Table 7. Once again, denser plantings show higher deposits, hence greater capture efficiency. The closeness of adjoining canopies in the denser plantings (M.26) also allows a greater potential for obtaining some next row spray deposition, which is useful for ART practices.

Finally, the tests in the peach block confirm results in apples, i.e., orchard geometry can play a significant role in ultimate spray deposition (capture efficiency). Total average residues per system that had an additional teatment of side mechanical shearing are noted in Table 8. The narrower canopy of the fan system showed the highest deposition efficiency while the shearing resulted in highest deposits in fan systems. From these results, it is clear then that any significant change in the horticultural management of an orchard may influence the level of spray depositon.

In summary, these and other studies show that the following parameters play a key role in determining the amount of spray deposited within a true canopy.

Parameters Affecting Spray Deposition in Tree Canopies:

1. **Tree Height:**
   One of the principal factors in inadequate deposition patterns (Figure 2a—value for x).
2. **Nozzle to Tree Row Distance:**
   Deposit patterns are also affected by foliage density and tree canopy diameters (Figure 2a—values for y and z).
3. **Nozzle to Canopy Edge:**
   This distance can become critical when sprayer capacity and high ground speeds (Figure 2a—value for z) are matched incorrectly.

Table 6. Orchard size and spray deposition[1]

Orchard and site		Avg μg carbaryl per 50 leaf discs[1]	Overall mean μg/tree
North	Sprayer side	2076 b	1656
	Tree row	1236 c	
M.9	Sprayer side	2517 b	2337 (+41)
	Tree row	2157 b	
M.26	Sprayer side	3765 a	3437 (+107)
	Tree row	3110 a	

[1]Sprays all applied with Myers 2A36 sprayer, figures in ( ) represent % increase over data for North orchard.
[2]Means followed by same letter are not significantly different at P=.05 level (DNMRT).

Table 7. Spray deposition potential for alternate row spraying.

	Avg ug azinphosmethyl/50 leaf discs[a/]		
Orchard	Spray side	– Rows from sprayed row 1	2
North	305	33	0
M9	423	21	0
M26	854	69	14

[a/] Myers 2A36 airblast sprayer at 2 mph in each system with 3X material.

Table 8. Interception of fluorescent dye by 3 peach management systems.

	Avg total μg dye/cm² x 10^{-3}[1]		
Training system	Sheared	Unsheared	% Change
Natural	72.27 a	37.37 a	48.3
Vase	74.32 a	61.15 b	17.7
Fan	161.10 b	73.74 bc	54.2

[1]Means in each column followed by the same letter are not significantly different at P=.05 level (DNMRT).

4. **Tree Shape:**

   Pyramid tree shapes have less foliage (than oval tree shapes) as a barrier to top center deposition patterns (Figure 2b).

5. **Cultivar, Tree Age and Rootstock:**

   All three play a role in determining ultimate shape and size and density of foliage.

6. **Crop Management:**

   Regulation of tree growth by pruning, growth regulators or attainment of maximum cropping potential has some effect on deposition process.

7. **Row Spacing:**

   A factor in spray gallonage and rates of pesticide use/acre. Row footage/acre increases as between row spacings decrease. As foliage targets become situated closer to the applicators, the conditions for good spray deposition change dramatically.

8. **Percent of Maximum Row Foliage:**

   Have the trees in the row attained their maximum spread and fill in the row? As the row reaches maximum foliage to form a tree wall and depending upon tree height and row spacings, the canopy air movement is also changed...which can affect the spray deposition process.

9. **Sprayer/Operator:**

   These two factors still account for a major part of the "efficiency" portion of the process. A mismatch of either one to adjust for changes in area and shape of foliar targets can result in the all-too-familiar comments of "overkill" or "the chemical did not work." Accurate control of travel speed and adjustment of liquid and air flow to the foliar target are critical for an efficient application. These adjustments are mandatory if one is to attempt "fine tuning" practices of integrated pest management when delivered doses are critical for survival of predators. In addition, over-spraying can also exacerbate pesticide resistance, a phenomenon which is becoming more of a critical problem for orchardists.

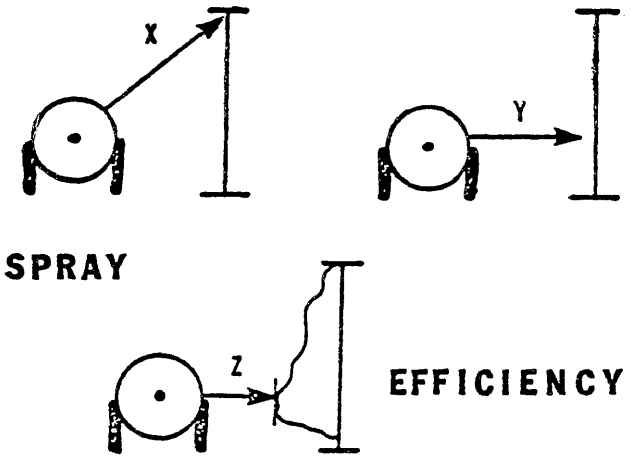

Figure 2a. Spray efficiency factors of tree ht (x), distance from sprayer to tree midline (y) and distance to tree canopy (z).

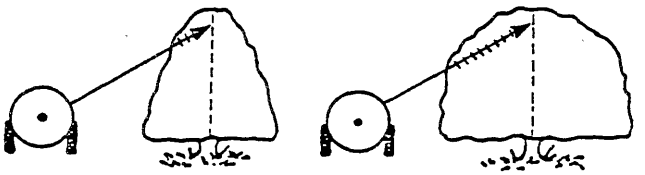

Figure 2b. Tree shape also influences spray deposits in tops of tree canopies.

A definitive approach to more accurate tree spraying [tree row volume - TRV] has been identified and evaluated [Sutton and Unrath, and Byers et al. 5,6]. However, it has been our experience that many Ohio growers are already below the stated guidelines for adjustment for canopy volumes. Thus, while TRV represents a *guideline* for adjustments, individual strategies for each grower and orchard take precedence over the guide. In addition, the use of alternate row middle techniques [ARM] [7] is also a valuable addition to grower strategies, provided that technical precision is well managed and there is adequate attention to crop loss assessment within the orchard [8].

A practical approach for improving spray application was suggested by Hall (9) and included the following steps:

(1) map the orchard by block and plan the strategy for each block by cultivar, tree density, and production potential;

(2) identify the sprayer output per acre in each block according to the same factors; and

(3) for each combination of sprayer/block, identify the nozzle arrangement, the gallons/minute [GPM] for each, and the total output for each speed of travel and pressure combination. Finally, note the adjustments that can be made for each block, i.e., changes in GPM with 1-4 nozzles shut off; changes in GPA with speed increase/decrease; psi adjustments, and alternate middle applications. This nozzle chart would thus designate for each block, the nozzle/disc combination and their GPM output dor selected pressures and travel speeds. Record the details on a flip card system and place the cards on a rack next to the tractor seat.

The use of variable rates in one block versus another depending upon the pest situation, or cultivar susceptibility, is a

more rational strategy for the use of these chemical tools. Serious consideration must be given to the potential of variable rates because of their *cost reducing values*, and enhancement of IPM strategies. However, with some of the current spray machinery, it is cumbersome and time consuming to make these adjustments ... or is it? The nozzle disc/core combinations can be "charted" in the spring. So when #1, #2, and #9 are shut off, for example, it is a reduction in GPM of 10 or 20 percent, etc. The tree height can be adjusted by changing the air flow patterns. Or in the case of low volume equipment, the flow rate dials can be changed. And the pressure and speed of travel can be adjusted (if they have *functional* gauges). Or alternate row procedures can be used. Anyone of the aforementioned steps only requires two things: (1) that the grower knows "what happens" with that adjustment, and (2) that the operator gets down off the tractor seat in different blocks and "*does it.*" Such adjustments are aided by the use of food dyes or fluorescent tracers and cards placed in trees to establish spray patterns within different blocks. It may only take 10 minutes or so per block to significantly improve the precision of pesticide application in that block, but the orchardist has to take the time to do it.

Growers frequently state that they are spending too much on crop protection chemicals, but they are unable to estimate the amount-per acre, per packed bushel, or the scale of block and cultivar productivity, quality and profitability. If application costs are examined in relation to production units, i.e., crop yields and quality,it is easy to translate pesticide use to costs and benefits per unit of production (bushels per acre). These data directly tell the story of cost effectiveness of the pesticide and application from which growers can better plan future strategies for crop protection. Coupled with the use of on-farm decision aids such as MARKET MODEL [10], increased information about relationships between production/costs/benefits will *greatly decrease* (1) the reliance on additional sprays as "insurance" and (2) the perception of increased risk associated with any change in a crop protection strategy.

Conclusions

Keeping pesticides on target, i.e., defining that target, and making appropriate adjustments in spray delivery protocols (11), is going to be a very important issue for the tree fruit grower in the 1990's. Faced with increasing spray costs and regulations, management strategies that address these issues will clearly pay dividends for the grower who is willing to invest the management expertise to solve these problems.

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AIR TEMPERATURE INTERACTIONS WITH MICROCLIMATE IN AN ORCHARD CANOPY

R. D. FOX and R.D. BRAZEE[1]

INTRODUCTION

Microclimate in an orchard canopy is an important factor in development of fruit crops. For example, microclimate can influence bee activity during pollination, affect development of fruit-skin blemishes, and contribute to the color of ripened fruit.

Air temperature is a measure of heat content in an orchard canopy. It is only one of several microclimatic variables; but because heat interacts with other microclimate state variables, temperature is a key to understanding microclimate.

Temperature is in itself an important factor in fruit crop development. Temperature is a controlling factor in growth, flowering, and evapotranspiration. It is an essential factor along with light in photosynthesis. In pest management, temperature enters into development of insect and disease infestations, and into the application of control measures through, for example, spray evaporation and retention, air movement, and activity of pest control agents. Temperature profiles should be important considerations as we seek to improve orchard management systems, including such operations as pruning. Temperature and its interactions with airflow, radiation, and humidity is an obvious factor in incidence of cold damage. The objective of this study was to measure and compare temperature profiles in an orchard canopy with other climatic variables in order to determine interactions in a canopy.

The shape of temperature profiles in some plant canopies has been fairly well established (Fox et al., 1980a, 1980b; Lemon et al., 1971; Lang et al., 1983). Factors that can cause variations in temperature profiles are wind, soil and air temperatures, solar radiation and cloud cover, and plant foliage.

Stability

The microclimate of an orchard canopy can be classified by defining atmospheric stability which, in turn, is reflected by the change in temperature with elevation above the ground surface, i.e., the temperature lapse rate. The so-called *adiabatic,* or *neutral,* lapse rate is a 10°C decrease per kilometer, which increases air density in exactly the same proportion as the decrease in atmospheric pressure with elevation reduces air density. Thus, as elevation increases, each packet of air has the same density as the air above and below, and there is little tendecny for verticle air motion. Neutral conditions usually occur with limited radiation exchange between the earth's surface and space, as in overcast days or nights or near sunrise or sunset.

When temperature decreases at a greater rate than the neutral rate, the condition is *unstable.* Unstable conditions usually occur on sunny days that produce warm air near the surface. Vertical air currents develop and air mixing is promoted.

Stable conditions occur when temperature decreases at a rate less than the neutral rate or actually increases with elevation. This condition is typical of inversions wherein vertical mixing is inhibited. Cool air remains near the surface and can flow downhill into low-lying areas.

Inversion layers are limited to levels near the earth's surface; above several hundred meters the normal temperature lapse rate exists. One cause of stable conditions is cooling of the ground surface by radiation during clear nights, as in radiation frost situations.

MATERIALS AND METHODS

The site for these experiments was at the OARDC Horticulture Unit 2. The temperature profiles reported here were measured in "Pyramid" form dwarf apple trees (Funt et al., 1983). Experiment 85-01 was prior to fruit set; Experiments 84-13 and 84-15 were post-harvest; and apples were on the trees for Experiment 87-13. The plots were approximately 100 x 100 m with two East-West driveways through the plot. The distance from the windward edge of the plot to the sensor position depended upon wind direction, but was always less than 50 m. Fritschen (1985) reports that wind flowing through a forest reaches equilibrium in 2-3 tree heights in a forest. With trees in spaced rows in orchards, the distance may be greater. Due to the limited orchard size available, microclimate conditions may not have been in complete equilibrium, with air flow affected by nearness to the edge of the plot. In Ohio, many orchards are small, so that equilibrium conditions may rarely be attained and the plots are thus representative of such orchards.

Temperatures were measured with aspirated, radiation-shielded copper-constantan thermocouples using a 65.6°C temperature reference. Temperature points were sampled in sequence, each point sampled about once per minute. To reduce variability in individual sample points, 1000 temperature readings were made each time a temperature point was sampled. These readings were made in approximately 0.25 seconds. The temperature value for each point was the mean of these 1000 readings. Average values were calculated for intervals of 5, 15, 30, and 60 minutes; averages calculated at 5-minute intervals included four samples because

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no samples were taken while the results were printed. Temperatures plotted in all figures were calculated at 15-minute intervals.

RESULTS

Temperature profiles were measured in orchard plots over a wide range of meteorological conditions. Profiles shown in Figures 1-4 are examples chosen from selected microclimate experiments to illustrate interactions between temperature and other variables. All times are EST; at Wooster, solar noon occurs at approximately 1220 EST.

Experiment 85-01, April 26, 1985, took place on a clear, sunny and warm day in early spring, with air temperature 10°C greater than soil temperature (10 cm below soil surface) at 0915, indicative of unstable conditions. The apple trees were in full bloom, the leaves small and the canopy quite open. Temperature profiles during four time periods are shown in Figure 1. These profiles show the effect of solar angle. At 0917, the sun warmed the thin canopy more than the soil surface; by 1119, the highest temperature was near the soil and the lower portion of the canopy (about 1-2 m above the ground) was warmer than the air above. A brisk wind kept exchange processes great enough that the temperature gradient through the upper portion of the canopy was almost zero. By 1621, solar angle was again low and temperature near the soil decreased. Highest temperatures were again within the tree canopy.

Experiment 84-13 on October 15, 1984 illustrates the effect of cloud cover on temperature profiles. Two temperature profiles were measured, one up to 4.3 and the other up to 8.5 meters (Figure 2). In the fall, the solar angle is low so the plant foliage intercepted more solar energy than the soil surface and temperatures were higher in the top of the canopy than mid-canopy; temperatures increased near the soil, probably due to more airflow under the thickest part of the canopy. Thus, there was some indication of instability.

After 1500, the sky became overcast with intermittent light rain; temperature profiles became nearly uniform from top to bottom as we would expect for nearly neutral stability conditions.

Experiment 84-15, November 13, 1984, was conducted on a cool, clear day after most leaves had fallen from the apple trees. Figure 3 is a plot of temperature profiles measured by two systems. The wind was less than 2 m/second for most of the day; mixing of atmospheric flow through the canopy was not great. From 1200-1500, the warmest temperatures were near the ground, because (1) soil temperatures were much greater than air temperatures and (2) lack of foliage allowed solar energy to reach the soil surface. These developments would encourage some instability. After 1600, air temperatures near the ground became less than temperatures within the canopy which were less than air temperatures above the canopy, tending toward stable conditions. The reason for this phenomena is that radiation to the cold sky was greater than solar radiation at this time of day during the fall season.

Experiment 87-13 was conducted on August 6, 1987. Some of the orchard plot had been removed, one block, about 100 x 25 m, remained. August 6 was warm and sunny with wind from the NW at less than 1 m/second. Figure 4 is a plot of two temperature profiles; one near the east edge of a tree canopy and the other near the west edge of the same tree. The canopy was fully developed. During the morning hours, both temperature profiles were nearly equal; about 0900 temperatures in the east profile became slightly warmer than the temperature profile on the west side. Then, after about 1300, temperatures in the west profile became slightly warmer than temperatures in the east profile. After 0900, most temperature profiles assumed a typical unstable summertime shape for sunny days, with warmer temperatures near the ground and in, and above, the canopy. The coolest temperatures occurred at a level corresponding to the widest and densest part of the canopy .

SUMMARY

Atmospheric stability conditions are reflected in the general shape of temperature profiles within an orchard canopy, temperature being an essential factor in quality fruit production. Local microclimate factors such as solar radiation, cloud cover, wind velocity, soil temperature and plant canopy density were shown to modify the shape of temperature profiles. Temperature profiles were obtained in a canopy of pyramid-form semi-dwarf apple trees for (1) thin canopy, unstable conditions; (2) post-harvest full-canopy, neutral conditions; (3) thin canopy near-stable conditions; and (4) full canopy unstable conditions.

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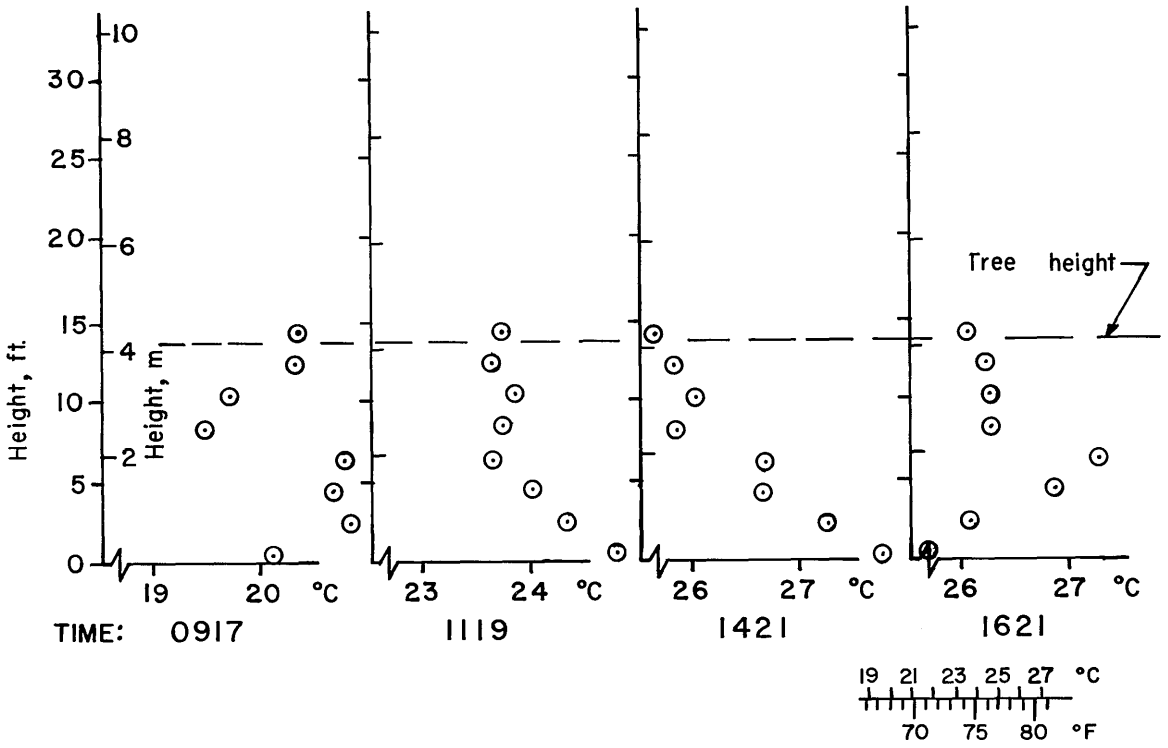

Figure 1. Temperature profiles within an orchard canopy in April, 1985. Climatic variables were: Wind velocity: south at 5.4 meters/second (12 mph); Soil temperature at 10 cm below surface: at 0917 16°C, at 1621 19.3°C; Sky conditions: clear.

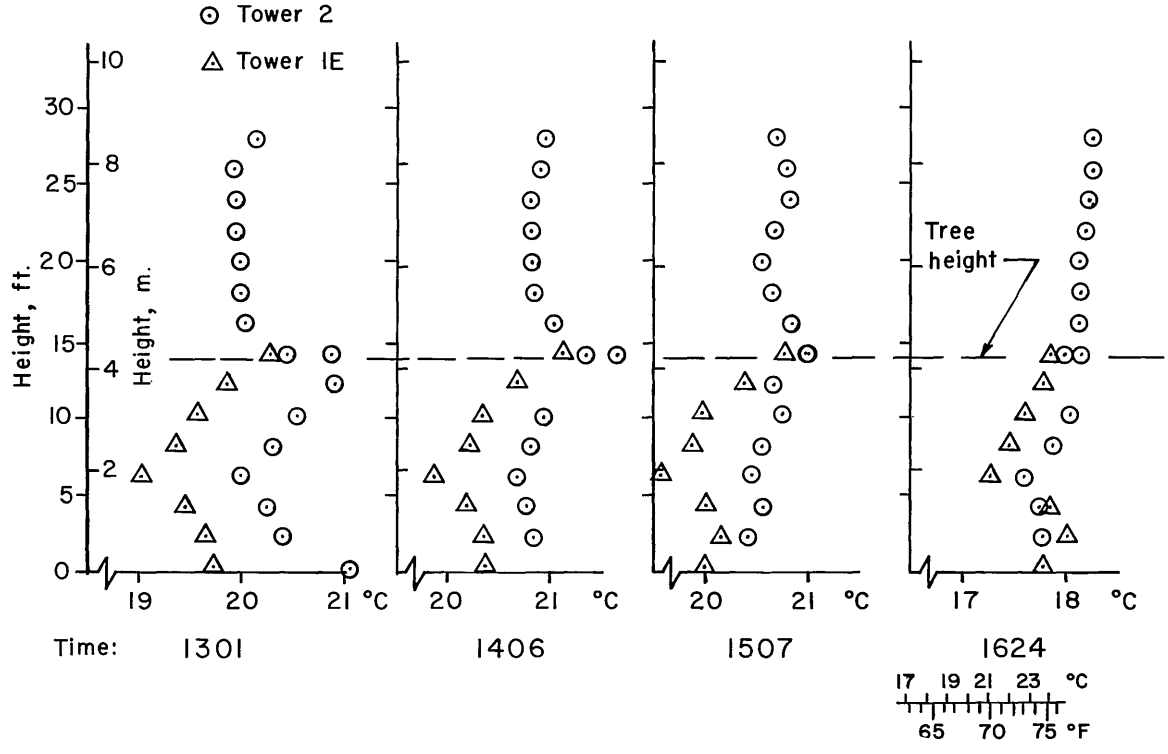

Figure 2. Temperature profiles within an orchard canopy in October 1984. Climatic variables were: Wind velocity: southeast to southwest at 1.5 meters/second (3.5 mph); Soil temperature at 10 cm below surface: at 1300 15.6°C,at 1500 16.2°C; Sky conditions: at 1300 clear with haze, at 1430 mostly overcast, at 1630 overcast with light rain.

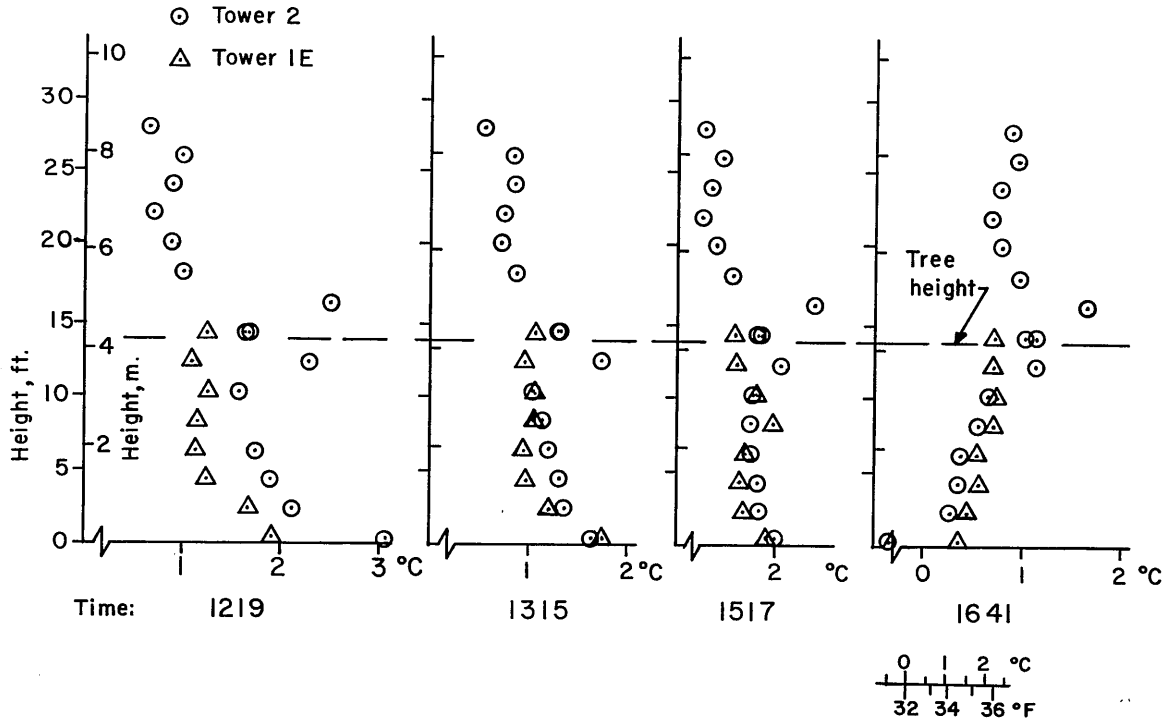

Figure 3. Temperature profiles within an orchard canopy in November 1984. Climatic variables were: Wind velocity: north at 2.2 meters/second (5 mph); Soil temperature at 10 cm below surface: at 1215 4.8°C, at 1641 4.6°C; Sky conditions: clear.

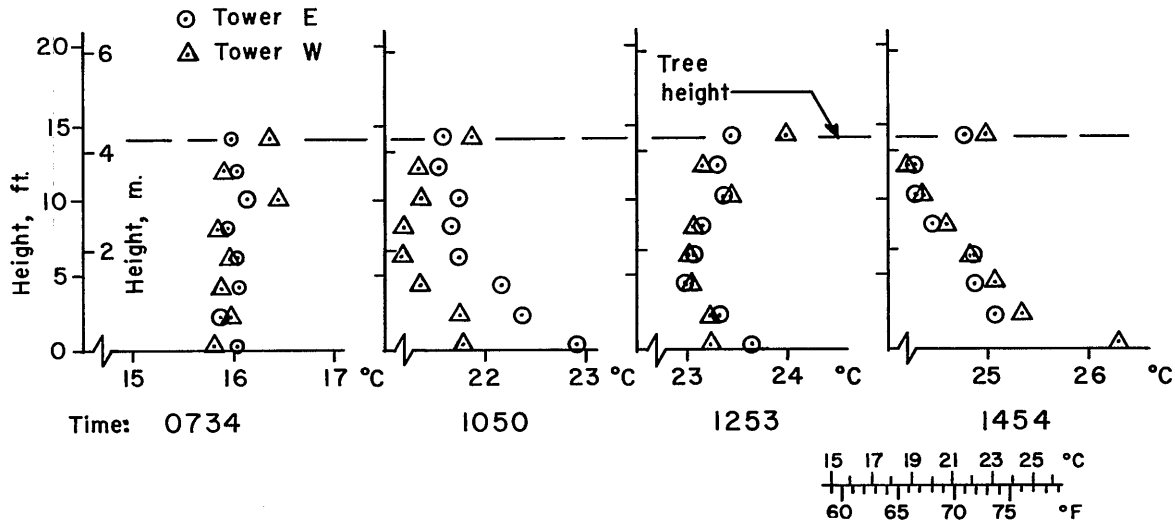

Figure 4. Temperature profiles within an orchard canopy in August 1987. Climatic variables were: Wind velocity: northwest at less than 1 meter/second (2 mph); Soil temperature at 10 cm below surface: at 0730 18°C, at 1300 18.3°C; at 1500 21.7°C; Sky conditions: clear.

MEASUREMENT OF APPLE POLLINATION EFFICIENCY BY HONEY BEES HIVED IN A PROTOTYPIC POLLINATION UNIT

Dr. James E. Tew[1] and Dr. Dewey M. Caron[2]

INTRODUCTION

In recent years, researchers have explored the feasibility of an inexpensive pollination unit for honey bees. This approach to pollination management was investigated due to substantially increased equipment and labor costs associated with apple pollination. Tew and Caron (1986) described a prototypic pollination unit that was made from expanded polystyrene, was inexpensive, and simple to manage. Very few studies have been conducted using polystyrene as a hive material. In standard colony studies, Barker and Jay (1974) compared the foraging activity of bee colonies with large and small populations. Their data indicated there were no significant differences in the proportion of incoming foragers or weights of pollen collected.

In this study, overwintered colonies (Alabama and Maryland) and colonies started from package bees (Alabama and Maryland) were evaluated. Overwintered verses package studies were undertaken to evaluate foraging activity from each type colony. It is not uncommon for commercial beekeepers to use colonies started in warmer climates and later moved to northern states for pollination services. Occasionally, package bees are put into pollination service. Studies were included that would compare the value of package pollination units to the more developed overwintered colonies.

METHODS AND MATERIALS

Experimental pollination units were constructed of expanded polystyrene foam 2.54 cm thick (Tew and Caron, 1986) and were placed in three selected Maryland apple orchards. Six colonies were placed in a 0.4 ha block of 'Delicious' apple trees at the University of Maryland's research farm. Four of the colonies were started from packages. The remaining two colonies were overwintered in College Park, Maryland. These six colonies consisted of three polystyrene foam colonies and three standard control colonies.

The second location was in Beltsville, Maryland, on the USDA's main research farm. Ten colonies were placed in a 1.2 ha block of 'Red Delicious', 'Yellow Delicious', 'Jonathan', and 'Rome' apple trees. Polystyrene foam colonies consisted of two package (0.9 kg) colonies started in April in College Park, one package colony begun in late February in south Alabama, one colony overwintered in College Park, and one colony overwintered in south Alabama. Five foam colonies were compared to five control colonies in standard equipment. Control colonies were started in the same manner used to start test colonies.

A third location was selected at Hancock, Maryland, approximately 144 km from College Park. The blooming period of orchards in the Hancock area is about two weeks behind those in the College Park area. Counts were made May 10-20. Thirty colonies (15 foam and 15 control colonies) were placed in a 6 ha block of 'Rome' and 'Jonathan' apple trees. Colonies observed were randomly selected from all four test groups. Comparable control colonies were randomly selected and observed in the same manner as test colonies. At each location, observations were made to determine when foraging activity began from each colony in the study. A second observation (a 1-minute count) was taken to monitor incoming bees. During the second count, bees returning with pollen (from any source) were noted. Counts were made throughout the day at 1-1/2 hour intervals.

After foraging activity counts were made, 35 returning bees were collected and sacrificed. Pollen on, or in, bees collected in this fashion was used to determine where bees had been foraging.

Twice during each sampling day, pollen traps were fitted to both types of colonies. Traps were installed about the time pollen began to be collected (around 0900) and were left on until noon. Pollen collected was used to formulate conclusions as to what percentage of bees foraging were on the desired crop. Quantity was not considered significant.

RESULTS AND DISCUSSION

Foraging Activity From Foam Colonies

Entrance activity studies were conducted at two sites. Location of the first entrance activity replication was in apple orchards at College Park, Maryland. Data collected from a visual count at colony entrances indicate the largest numbers of bees returning to control colonies were started in Alabama (DST)* (64.2 bees/min) (Table 1). These colonies also had the greatest number of pollen collectors (24.8%); however, the largest percentage of bees returning with pollen was found in foam colonies overwintered in Alabama (DOW). These colonies also exhibited the greatest flight and pollen collection activity of the two groups.

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*CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.9 kg of adult bees at College Park, Maryland.
DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.9 kg of adult bees at Dothan, Alabama.

Table 1. Mean number of apple pollen foragers returning to colonies at College Park, MD

Colony Type[a]	Ave. No. Returned/Min.		Ave. No. Pollen Foragers/Min.[b]		% Pollen Foragers	
	Foam	Control	Foam	Control	Foam	Control
CPOW	31.7	41.9	7.0 de	6.3 ef	22.0	15.0
CPST	19.0	39.4	0.8 f	4.6 f	00.04	11.6
DOW	39.2	53.5	11.9 a-c	14.3 ab	30.4	26.6
DST	36.7	64.2	10.7 b-d	15.9 a	29.1	24.8
Mean	31.6	49.7	7.6	10.3	24.0	20.6

[a]CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.9 kg of adult bees at College Park, Maryland
DOW=colonies overwintered at Dathan, Alabama
DST=colonies started from 0.9 kg of adult bees at Dothan, Alabama
[b]Means followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

When the two most efficient pollen collecting units (DOW Foam and DST Control) were analyzed statistically, no significant difference was found at the 5 percent level.

Colonies that consistently did poorest were both foam and control colonies started as packages at College Park (CPST). CPST foam colonies averaged less than one bee per minute while control package start colonies averaged 4.6 bees/min. Differences were not significant at the 5 percent level.

Foraging activity data indicate that foam pollen collection percentages were not significantly different than figures generated by counting returning pollen foragers (21.3% vs. 24.0%, t.05(82)=.09) (Table 2).

Nectar (or water) collectors comprised almost half the returning population in foam and standard colonies (Table 2). Small numbers of bees from foam and control colonies were collecting both pollen and nectar. Bees orienting or foraging unsuccessfully comprised 28.2 percent (foam) and 29.4 percent (control) of returning populations. No significant difference existed between the four foraging categories.

Apple Pollination Evaluation

At the onset of apple petal fall in College Park, randomly selected colonies from each colony group (ie., CPOW, CPST, DOW, DST) were placed in apple orchards near Hancock, Maryland, where bloom is 2-3 weeks later than in College Park. Hancock observation consisted of monitoring all bees returning and bees returning with pollen for a 1-minute count at approximately 1-1/2 hour intervals. Dothan package starts (DST) were the most active foragers of the foam group with an average of 201.0 bees returning per minute (Table 3). Of this population, 34.5 percent (69.4 bees/min.) were pollen foragers. The least active foam colony group were colonies overwintered at College Park. In this group, 14.4 of a total of 87.2 bees returning per minute were pollen foragers (16.5%). Data from control colonies indicated similar results.

Table 2. Foraging profile of foam and control units in apple pollination studies at College Park, MD.

	Colony[a] Type	Honey Bee Sample Size	% Foraging Activity			
			Pollen	Nectar	Both	Nothing
FOAM COLONIES	CPOW	39	17.9	20.5	02.6	59.0
	CPST	18	22.2	66.7	00.0	11.1
	DOW	40	25.0	50.0	05.0	20.0
	DST	40	20.0	57.5	00.0	22.5
% of Total Sample			21.3	48.7	01.9	28.2
CONTROL COLONIES	CPOW	40	20.0	37.5	00.0	37.5
	CPST	20	20.0	25.0	05.0	50.0
	DOW	40	25.0	62.5	00.0	12.5
	DST	40	27.5	55.0	00.0	17.5
% of Total Sample			23.1	45.0	01.3	29.4

[a]CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.9 kg of adult bees at College Park, Maryland
DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.91 kg of adult bees at Dothan, Alabama

Table 3. Mean number of apple pollen forages returning to colonies at Hancock, MD.

Colony Type[a]	Ave. No. Returned/Min.		Av. No. Pollen Foragers/Min.[b]		% Pollen Foragers	
	Foam	Control	Foam	Control	Foam	Control
CPOW	87.2	84.60	14.4 b	18.6 b	16.5	22.0
CPST	117.4	136.00	19.6 b	18.4 b	16.7	13.5
DOW	125.4	94.20	18.6 b	23.2 b	14.8	24.6
DST	201.0	149.40	69.4 a	27.9 b	34.5	18.7
Mean	132.8	116.05	30.5	22.0	23.0	19.0

[a]CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.9 kg of adult bees at College Park, Maryland
DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.9 kg of adult bees at Dothan, Alabama
[b]Means followed by the same letter are not significantly different at the 5% level (Duncan's Multiple Range Test).

Dothan package starts (DST) were once again most active (149.4 bees/min). Of the average number of returning bees, 18.7 percent (27.9 bees/min) were pollen foragers.

Control colonies wintered in College Park (CPOW) were the least active. An average of 84.6 bees/min. returned to this colony type. Approximately 22.0 percent (18.6 bees/min.) were pollen foragers. Even though DST control colonies ranked number 1 out of 4 in pollen foraging, they dropped to third position if percentage of returning bees carrying pollen was used as the determining criterion.

Statistical analysis of pollen foraging data of DST foam and DST control indicated the mean differences were significant at the 5 percent level (DST foam 34.5, DST control 18.7).

Foam pollen forager percentages supported data acquired by visual count of returning pollen foragers (Table 4). The overall foam pollen foraging mean was 10.2 bees/minute. Almost half the returning population were nectar (or water) foragers. Eight foragers returned with both pollen and nectar in foam and control colonies. Roughly one-third returned empty.

College Park—Hancock Colony Comparison

Comparison of College Park and Hancock data indicates comparable results (Table 5). An average of 24.0 percent of the total bees returning were pollen collectors in foam colonies, while control colonies averaged 20.6 percent at College Park. Results of studies conducted at Hancock, Maryland, indicated 30.5 percent of the returning population from foam colonies were pollen foragers while 22.0 percent were pollen foragers from control colonies. In both experiments, foam colonies had higher percentages of pollen collections. When pollen foraging means were studied, however, foam colonies did poorer at College Park, but improved significantly during Hancock studies. Foam colonies averaged 7.6 pollen foragers/minute while control colonies averaged 10.3 foragers/minute. Both foam and control

Table 4. Foraging profile of foam and control units in apple pollination studies at Hancock, MD.

	Colony[a] Type	Honey Bee Sample Size	% Foraging Activity			
			Pollen	Nectar	Both	Nothing
FOAM COLONIES	CPOW	50	18.0	42.0	04.0	36.0
	CPST	50	20.0	40.0	00.0	40.0
	DOW	40	17.5	62.5	02.5	42.5
	DST	52	28.8	51.9	00.0	15.4
% of Total Sample			21.1	49.1	01.6	33.5
CONTROL COLONIES	CPOW	51	23.5	54.9	00.0	19.6
	CPST	50	20.0	46.0	02.0	32.0
	DOW	50	22.0	40.0	04.0	34.0
	DST	47	20.0	44.0	04.0	32.0
% of Total Sample			21.4	46.2	02.5	29.4

[a]CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.9 kg of adult bees at College Park, Maryland
DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.9 kg of adult bees at Dothan, Alabama

pollen foraging populations increased substantially from College Park to Hancock. In these tests, foam colonies averaged 30.5 pollen foragers/minute while control colonies averaged 22.0 pollen foragers/minute.

The combined apple pollination data at College Park, Maryland, and Hancock, Maryland indicates DOW colonies had the largest number of pollen foragers (11.9 foragers/minute) returning to foam units (Table 6). However, DST control colonies had more returning pollen foragers (15.9 foragers/minute) and had the most active foragers in the control group. Mean differences between foam and control colonies were significant at the 5 percent level. DST foam colonies averaged 69.4 pollen foragers/minute when tested at Hancock, Maryland, while DST colonies had the most pollen foragers returning (28.0 pollen foragers/minute). Mean differences were significant at the 5 percent level. A statistical overview of all apple pollination studies indicated foam colonies were significantly better pollen foragers than control colonies. Throughout apple studies, foam colonies averaged 19.0 pollen foragers/minute while control colonies averaged 16.5 pollen foragers/minute. Reasons for this difference are not well understood. Brood production and average colony temperatures were not significantly different.

Pollen traps were used to collect pollen to determine what percentage of foragers were visiting apple blossoms for pollen. Pollen foraging rates from foam colonies were slightly greater than control colony rates (Table 7), but the means were not significantly different. Mean pollen trap sample weights were 134.2 g collected by foam colonies and 128.6 g collected by standard colonies.

A scatter plot of pollen foraging throughout the daylight hours (Table 8) indicated curvilinear regression in some College Park tested groups, but not in others. The coefficient for all College Park groups had a calculated value of .06. This correlation ratio was not considered significant (F=.02, table 4.9) at the 5 percent level indicating no curvilinear function. Vansell (1942) had observed a curvilinear function in pollen foraging in pears. He reported that pollen foraging visits to pears began at 0800, peaked out at noon, and rapidly declined thereafter.

There was substantial variation between group foraging times (Table 8). Computation of F values gave evidence of significant variations among individual pollen foraging means in both groups. College Park package starts foraged for pollen during mid and late morning hours. All overwintered colonies (compared as a group) had comparable percentages throughout each time period. However, DOW and DST colonies tended to have slightly higher ratios in early morning and late afternoon foraging.

Tested and control mean percentages of apple pollen foragers for College Park and Hancock, along with combined group means, indicated College Park foragers worked early to mid-morning (Table 8). Hancock foragers exhibited highest levels of foraging mid to late morning with a slight increase in late afternoon.

Combined means of both groups yielded data that compared favorably with data collected by Johansen (1956). He reported that pollen foraging was greatest in mid-morning to early afternoon (1000-1300) hours with slightly increased activity in late afternoon.

A comparison of all foam colonies vs. all control colonies (College Park and Hancock) at specified time intervals indicated both groups foraged predominately from mid-morning to early afternoon 1000-1300) (Figure 1). Both groups exhibited the least activity from 1400-1559. Standard colonies began to forage earlier than foam, but foam showed more foraging activity in late afternoon (1600-1800). Grand means (% bees returning with pollen) were 21.2 percent and 19.4 percent for foam and control, respectively. Differences in these means were not significant at 5 perent (t5(.05)=.8).

Table 5. Comparison of combed pollen foraging activity, College Park, Hancock

	Foam	Control	Foam	Control
Mean number of bees returning	31.6	49.7	132.8	116.1
Mean pollen collectors	7.6	10.3	30.5	22.0
Percentage of returning bees carrying pollen	24.0	20.6	23.0	19.0

Table 6. Comparison of pollen foraging rates of the four most active colonies[a] from two locations

	Foam Colonies	Pollen Forages/ Minute	Control Colonies	Pollen Forages/ Minute
College Park, MD	DOW	11.9	DST	15.9
Hancock, MD	DST	69.4	DST	28.0
Overall	Foam	19.0	Controls	16.5[b]

[a]DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.9 kg of adult bees at Dothan, Alabama
[b]Significantly lower than foam ($t_{.05}$)

Table 7. Percentage of apple pollen collected by foam and control colonies[a]

	Foam		Control	
	% of Pollen From Apple	Sample Weight (g)	% of Pollen From Apple	Sample Weight (g)
College Park				
CPOW	96.4	87.9	97.7	73.7
CPST	97.1	73.7	96.5	31.1
DOW	94.3	103.4	91.3	150.3
DST	92.8	116.2	95.4	133.2
Hancock				
CPOW	96.7	144.6	95.6	121.9
CPST	95.1	130.4	96.3	121.9
DOW	99.1	187.1	97.4	201.3
DST	97.6	201.3	95.7	195.6
Means[b]	96.3	134.2	95.7	128.6

[a]CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.9 kg of adult bees at College Park, Maryland
DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.9 kg of adult bees at Dothan, Alabama
[b]Means not significantly different at the 5% level

SUMMARY

Results of apple pollination studies indicated that polystyrene foam units averaged 19.0 pollen forgers/minute while control colonies averaged 16.2 pollen foragers/minute. Standard colonies began to forage earlier than polystyrene foam, but foam colonies worked longer during afternoon hours. Both types of colonies were least active from 1400—1600 hours. Overall percentage of pollen foragers for foam and control (21.2% and 19.4%) were not significantly different.

In practically all tests, polystyrene foam colonies performed as well as comparable control colonies. The compact, lightweight, prototypic polystyrene foam colonies would appear to have potential as an economical pollination unit.

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Table 8. Percent returning bees as pollen forages in apple pollination studies

	CPOW[a]				CPST				DOW				DST			
	College Park		Hancock		College Park		Hancock		College Park		Hancock		College Park		Hancock	
	Foam	Std[b]	Foam	Std	Foam	Std	Foam	Std	Foam	Std	Foam	Std	Foam	Std	Foam	Std
0800-0959	10.0	29.8	3.4	35.7	00.0	16.5	13.3	20.0	35.5	29.5	2.8	29.9	26.4	16.4	25.9	11.6
1000-1159	26.6	8.7	15.1	8.6	10.2	15.0	24.5	14.5	24.2	27.1	10.7	21.3	29.7	36.5	44.1	30.8
1200-1359	22.6	16.3	20.0	36.1	2.7	8.8	19.1	29.5	16.6	27.2	14.3	20.5	35.1	22.0	32.9	12.9
1400-1559	26.1	24.1	30.9	29.6	2.1	8.3	17.6	7.2	22.2	23.6	17.0	32.3	28.8	17.6	5.7	9.4
1600-1759	20.9	11.8	16.7	13.9	3.2	3.3	7.9	17.2	39.0	25.4	24.6	23.4	26.1	23.1	38.6	23.2

Totals—Foam and Control

Time	Ave College Park	Ave Hancock	Grand Mean
0800-0959	20.5	17.8	19.2
1000-1159	22.25	21.2	21.7
1200-1359	18.9	23.2	21.1
1400-1559	19.1	18.6	18.9
1600-1759	19.1	20.7	19.9

[a]CPOW=colonies overwintered at College Park, Maryland
CPST=colonies started from 0.91 kg of adult bees at College Park, Maryland
DOW=colonies overwintered at Dothan, Alabama
DST=colonies started from 0.91 kg of adult bees at Dothan, Alabama
Std=Standard Control Colony

MEASUREMENTS OF CUCUMBER AND SOYBEAN POLLINATION EFFICIENCY BY HONEY BEES HIVED IN A PROTOTYPIC POLLINATION UNIT

Dr. James E. Tew[1] and Dr. Dewey M. Caron[2]

INTRODUCTION

Cucumber Studies

Cucumber studies conducted in Michigan demonstrated that bees collected nectar from both staminate and pistillate flowers, but few bees collected pollen (Collison, 1973). Kauffeld *et al.* (1975) conducted cage and field studies of cucumbers in Louisiana. Results indicated honey bees were responsible for increased yields in caged studies.

Soybean Studies

Soybean pollination data is contradictory. Morse and Carter (1973) concluded that soybeans were self fertile and did not benefit from insect pollination. Erickson and Garment (1978) demonstrated honey bees routinely visited soybean blossoms under specified conditions. Jaycox (1970) and Blickenstaff and Huggans (1962) reported that few honey bee foragers were found on soybeans.

Milum (1940) conducted cage studies on soybeans and found no yield differences in open vs. closed plots. Erickson *et al.* (1978) reported a 21.6 percent yield increase in caged plots with honey bees. Weber, Empig, and Thorn (1970) noted soybean heterosis must occur for hybrid seed production to be successful. Mason (1979) felt that indeterminate varieties were more attractive than determinate soybean varieties. Mason indicated more research was necessary for conclusive results.

In recent years, there has been increased interest in developing a male sterile soybean. Caron and Waller's (personal communication) unpublished data indicated expanded polystyrene colonies (foam) were successful as cage pollinators. To further investigate their observations, foam colonies were used to investigate the biology and cage management of honey bees foraging on soybeans in male sterile soybean cage studies at Queenstown, Maryland. Pollination studies presented in this work were conducted using lightweight, simple expanded polystyrene hives described by Tew and Caron (1986).

METHODS AND MATERIALS

Twenty-one randomly selected colonies (11 polystyrene foam and 10 control) were placed in a 13.6 ha planting of 'Poinsette' cucumbers near Salisbury, Maryland on June 20. Polystyrene foam colonies were the type described by Tew and Caron (1986). Three groups of colonies were tested. The first group consisted of three foam colonies originating as packages begun in Maryland. Because they were not routinely fed during early development, this group had low honey and pollen stores and adult populations. Consequently, they were not as strong later in the year as the other types of test colonies. A second group consisted of four control colonies, two of which were supered as needed. This group was tested to compare the foraging population and behavior of colonies that were allowed to go to full strength to those that were given limited space. The third group was made up of seven foam and seven control colonies that had been equalized in populations and honey and pollen stores. The average gross weight was 18 kg $\pm$ 0.2 kg. Studies described earlier indicated 16 kg approached the maximum weight limit for expanded foam colonies (Tew and Caron, 1986). Brood was equalized among test colonies, but was not removed from the test. Each colony had about 25 cm^2 of brood and 6.8 kg $\pm$2 kg of honey. Single story control colonies were reduced to an average weight of 33.2 kg. This weight (33.2 kg $\pm$ 1.5 kg) was proportional to reduced foam colony weights (16.8 kg $\pm$ 1.5 kg). Colonies were removed from cucumbers on July 21, 1978, after cucumber selling prices had dropped to an uneconomical level, making harvest unpractical.

Soybean varieties tested were 'Collam' and 'Williams'. Cages were 3.6 m x 3.6 m x 1.8 m. Each test consisted of a cage containing a standard one-story colony and two other cages each confining a comparable foam colony. Due to forager loss caused by flight disorientation in cages, colonies became weakened and were replaced after three weeks. Three different colonies were placed in the cages until the end of the soybean blooming period. Entrance activity along with bee populations (both brood and adult) were monitored. Assessments of honey and pollen stores were routinely made.

RESULTS AND DISCUSSION

Cucumber Pollination Studies Conducted at Salisbury, Maryland

The average number of bees returning to foam and control colonies and the number of bees returning with pollen was determined (Table 1). Examination of the data on pollen foraging shows that supered controls were the most active. An average of 82.1 bees/min. returned with 10.6 percent (8.7 bees/min) being pollen foragers. Unsupered controls were the least efficient pollen collectors of the three groups. Only 3.6 bees of an average 45.6 bees/min. were pollen foragers from these colonies. Statistical analysis revealed that pollen

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Table 1. Efficiency of cucumber pollen collection by honey bees foraging from different types of hives

	Types of Hive Equipment		
	Foam (10 Total)	Control (9 Total)	Supered (2 Total)
Bees returning/min.	39.9a	45.6a	82.1b
Mean Pollen collectors/min.	6.2c	3.6d	8.7c
Percentage pollen collectors	15.5	7.9	10.6

Means followed by same letter are not different at P=5%.

foraging between foam and supered groups was not significantly different while differences between supered control colonies and unsupered control colonies were significant at the 5 percent level ($t_{20}(.05)= .95$). Analysis of the number of returning bees indicated significant differences between supered colonies and the remaining two groups while the mean vlaues of bees returning to control and foam hives were not significantly different at the the 5 percent level ($t_{20}(.05)=.95$).

Approximately half the returning bees were nectar collectors (range 55-60 percent) (Table 2). Supered colonies were the most efficient pollen foragers followed by foam and unsupered controls, respectively. Foam colonies had the largest percentage of bees returning empty (without pollen, nectar, or water). Overall, supered colonies had more flight and pollen collection than the remaining two groups.

Foragers from supered standard control colonies collected 47 percent cucumber pollen, foam colonies collected 41 percent, and standard control colonies collected 39 percent. Means were not significantly different. Martin (1970) reported that cucumber pollen collection was poor and that bees foraged on cucumber blossoms predominately for nectar. He also stated that overhead irrigation systems adversely affected honey bee pollination; overhead irrigation was in use in the Salisbury test field.

Visual observations of entrance activity were recorded at two-hour intervals for colonies moved into cucumber fields. In all cases, pollen foraging was greatest during the first two hour interval (0800-1000) (Table 3). Connor (1969) found the best time for cucumber pollination in Michigan was 1000-1500. Sanduleac (1959) reported that varieties of *Curcurbita maxima, C pepo,* and *C. moschata* were heavily visited from 0600-1200 and that activity peaked around 0800-0900. In the Salisbury studies, pollen foraging was high during morning hours, but dropped dramatically during afternoon hours.

Table 2. Cucumber foraging activity of honey bees from expanded polystyrene and standard hive equipment

Types of Hive Equipment	Bee Sample Size	Foraging Activity (%)			
		Pollen	Nectar	Both	Nothing
Expanded Polystyrene	21	15.0	55.0	0.0	30.0
Unsupered Control	21	14.0	57.0	5.0	24.0
Supered Control	20	20.0	60.0	0.0	20.0

Table 3. Number of cucumber pollen foraging bees at 2-hour intervals

Types of Hive Equipment	Time and Mean Temperature(°C)				
	0800	1000	1200	1400	1600
	29.0	32.4	34.2	34.3	33.6
Expanded Polystyrene Colony					
Pollen Foragers	11.5	15.5	2.0	1.0	1.0
Total Bees Returning	27.0	75.0	49.8	31.5	16.3
% Pollen Foragers	42.6	20.7	4.0	3.1	6.1
Unsupered Control Colony					
Pollen Foragers	5.0	8.0	3.3	0.5	1.3
Total Bees Returning	22.5	116.8	33.3	20.5	34.8
% Pollen Foragers	22.2	6.8	9.8	2.4	3.6
Supered Control Colony					
Pollen Foragers	22.5	12.0	3.0	3.8	2.0
Total Bees Returning	67.5	111.0	73.0	81.5	77.3
% Pollen Foragers	33.3	10.8	4.1	4.6	2.6

Several researchers have reported cucumber to be a sporadic nectar secretor (Edgecombe, 1946; Kaziev and Seidove, 1965). Very little honey was stored by foam colonies in the pollination study. At the initiation of cucumber studies, all foam colonies had mean weights of 16.8 kg, ±2 kg while the controls were 33.2 kg. When colonies were removed from cucumbers, the mean colony gross weight for foam, control, and supered control was 14.9 kg, 27.8 kg, and 55.6 kg, respectively. Supered colony gross weights included 1 deep and 1 Illinois depth super above the single story brood nest.

Soybean Pollination Studies Conducted at Queenstown, Maryland

Normal soybean pollen foraging behavior was disrupted in cages. Bees tended to cluster at various places within the cage, therefore, activity counts were made on bees exiting from caged colonies (Table 4).

The largest numbers of bees exiting occurred at 1400 hours. Foam colonies had 6.5 bees/min. leaving while control colonies had 7.0 bees/min. exiting. Grand means were 4.4 bees/min. from foam and 4.0 bees/min. from control colonies. Means were not significantly different (P=.05).

Caged colonies were damaged. One polystyrene foam colony perished. Both foam and control colonies had a break in their brood rearing cycle. Colonies were moved to soybeans from cucumbers and were, therefore, light in honey stores. Pollen supplies were initially adequate; however, at the conclusion of soybean testing, pollen stores were exhausted, and all colonies were near starvation. Cooper and Emmett (1977) while working with runner beans and seed crops found that small experimental colonies in bee proof pollination cages did not store surplus honey. Supplemental autumn feeding was often required for survival.

SUMMARY

Polystyrene (foam) colonies, unsupered controls, and supered controls (colonies given space as required) were tested in a commercial cucumber planting. Supered controls were the most active pollen foragers (8.7 pollen foragers/minute). Foam colonies averaged 6.2 pollen foragers/minute while unsupered controls averaged only 3.6 bees/minute.

Results of studies with caged soybean plants indicated 4.4 bees/minute left from foam colonies while 4.0 bees/minute left from controls. Colonies in soybean cage studies suffered population decreases due to insufficient pollen and honey stores.

Table 4. Mean numbers of honey bees exiting hives per minute in caged soybean studies

Types of Hive Equipment	Mean Number of Bees Per One-Minute Count					Grand Mean
Foam	2.3	4.0	4.0	6.5	5.0	4.4
Unsupered Control	2.0	3.0	3.4	7.0	4.8	4.0
Time of Count	0800	1000	1200	1400	1600	

Grand Means not significantly different (P=.05)

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MICROPROPAGATION OF APOMICTIC *MALUS* CLONES OF DIVERSE PLOIDY LEVEL AND PARENTAGE

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INTRODUCTION

Apomixis, or asexual seed formation, exists within some species of *Malus*. Apomictic seeds have embryos that do not result from the fusion of embryo sac and pollen cells. This offers the possibility of virus-free clonal propagation via seeds, as apomictic seeds are genetically identical to the mother tree. The apomictic trait can be facultative, however; i.e., a proportion of the seeds can result from fertilization. Dr. Hanna Schmidt at the Fruit Research Institute in Ahrensburg, West Germany has evaluated *Malus* clones of diverse ploidy level and parentage for apomixis. Selected apomictic clones have been further evaluated for their potential as dwarfing rootstocks for commercial apple production (Schmidt, 1986). Limited material was acquired of eight of Dr. Schmidt's advanced selections that her trials have shown to have good yield efficiency while maintaining tree size in the dwarfing (M.9) to semi-dwarfing (MM.106) range.

Schmidt incorporated at least four species of *Malus* into this plant material, *M. sargenti* Rehd., *M. hupehensis* (Pamp.) Rehd., *M. sieboldii* (Regel) Rehd., and *M.* x *domestica* Borkh. Ploidy levels included diploid (2x=34), tetraploid (4x=68), and pentaploid (5x=85). These species are apomictic, except *M.* x *domestica*. Numbering systems, and information on seedling origin obtained from Schmidt, are presented in Table 1. Available information from Germany on percent apomicts, percent seed germination, and tree growth is presented in Table 2.

Table 1. Ohio and German numbering systems, and origin of *Malus* plant material micropropagated in this study.

Ohio No.	German No.	Origin
1	D1106	seedling of pentaploid hybrid between *M. sargenti* and the cultivar 'Croncels'
2	D2032	seedling of hybrid between *M. hupehensis* and the cultivar 'James Grieve'
3	C1812	second generation open pollinated seedling from *M. sargenti* hybrid
4	C1828	seedling of open pollinated *M. sargenti* hybrid[1]
5	C1827	seedling of open pollinated *M. sargenti* hybrid[1]
6	C0725	seedling of tetraploid *(M. sieboldii* x cultivar 'Husmoder') x *M. sargenti*
7	C1826	seedling of open pollinated *M. sargenti* hybrid[1]
8	D2212	seedling of open pollinated tetraploid *M. sieboldii* hybrid

[1]All derived from same mother plant.

Table 2. Percent seeds formed apomictically, percent seed germination, and tree growth characteristics for *Malus* clones micropropagated in this study. Information provided by Dr. H. Schmidt, West Germany.

Ohio No.	% Apomicts	%Seed Germinaton	Tree Growth Characteristics
1	60-65	60-70	Slow growing
2	60-80	70-80	MM.106 size, good yield efficiency
3	60-65	60-70	Slow growing
4	60-65	60-70	Slow growing
5	60-65	60-70	Slow growing
6	60-80	70-80	MM.106 size, good yield efficiency
7	60-65	60-70	Slow growing
8	60-80	70-80	MM.106 size, good yield efficiency

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The purpose of this study was to evaluate these apomictic clones to determine their ease of *in vitro* propagation. Another goal was to quickly obtain enough of this scarce plant material to enable fireblight and collar rot screenings and field performance evaluations in the U.S.A.

MATERIALS AND METHODS

Establishment of Aseptic Cultures

The stock plants used to obtain shoot tips were recently seed derived, and therefore, presumed juvenile, and it was expected culturing would be easier than with adult phase material. Two seedlings of each clone were selected for uniformity in the nursery after one growing season. They were dug in autumn 1985, planted in 4-liter pots, stored at 5-8°C for two months, and then placed under high intensity discharge (H.I.D.) lights in the greenhouse with a 17-hour photoperiod at temperatures of approximately 24°C day, 18° night. Terminal branches were tipped to encourage lateral bud growth and plants were fertilized with Osmocote 20-20-20 at the recommended rate. When new growth reached 3-6 cm length, shoot tips of 1-2 cm were cut, placed in plastic bags by clone, and immediately taken to the lab. Shoot tips were trimmed to 0.5-1 cm with outer leaves removed and placed in a dilute soapy water solution (Alconox in distilled water) on a magnetic stirrer for approximately 10 minutes. Tips were then transferred to a 10 percent Clorox solution (0.5% NaOCl) to which 1-2 drops of Tween 80, a surfactant, were added. Explants were agitated in this solution for 10-15 minutes, then solution plus explants were taken to the transfer hood. The sterilizing solution was decanted and tips were transferred, using flamed forceps, into three rinses of sterile distilled water. Tips were then placed into Petri dishes containing solidified (6.5 g/l Difco Bacto-agar) Murashige-Skoog (MS) medium (Murashige & Skoog, 1962) with a 4.4 uM (1 mg/l) benzyladenine (BA). Tips were transferred every 2-4 days for 12-20 days to fresh medium and contaminated explants were discarded. Successive batches of lateral shoots from stock plants were taken until 5-10 explants of each clone were established in aseptic culture.

Shoot Tip Culture

Contamination-free explants were transferred into 125 ml culture jars conatining 25 ml MS, 1 mg/l BA medium. Jars were placed on shelves in the tissue culture lab with 60 μEM^2sec^1 irradiance from suspended cool white fluorescent lights, 16-hour photoperiod, and 20-22°C temperature. Cultures were transferred to fresh medium every four weeks and numbers of cultures of each clone were increased by transferring from established cultures into additional jars. When microcuttings were removed, remaining basal clumps were transferred to fresh medium to allow additional shoots to emerge. When basal clumps became too bulky, cultures were restarted from single shoot tips.

Rooting Techniques

A. Non-Sterile

Microcuttings were cut at their base from the main clump of shoots when they were 2-5 cm in height. Lower leaves were removed and bases of cuttings were dipped in 0, 100, or 500 ppm indolebutyric acid (IBA) solution for 1-2 minutes. Cuttings were stuck, usually in groups of 20, into moistened 'Redi-Earth' soilless medium in 11 cm x 8.5 cm x 4 cm deep aluminum food trays with clear plastic lids. Individual cuttings were watered in by squirting distilled water around their base at the time they were stuck. Medium was maintained moist, but not so moist that free water could be poured from the container. Containers containing cuttings were placed on shelves in the tissue culture lab with environmental conditions as previously described for shoot tip cultures. After 2-6 weeks, depending upon the clone, rooted microcuttings were potted into cell pack flats containing 'Metro-Mix 150' and placed under intermittent mist (6 seconds every 6 minutes) and shade cloth in the greenhouse for one week. Plants were then placed under shade without mist for 3-5 days. Subsequently, they were placed under H.I.D. lights in the polyhouse and repotted and fertilized regularly to encourage vigorous vegetative growth.

B. Sterile

Microcuttings were selected as described in non-sterile rooting techniques. They were placed vertically in culture jars, 4-8/jar, with basal ends inserted into solidified MS medium containing 0.5, 1.0, or 2.0 mg/l IBA. Jars were placed on shelves in the tissue culture lab for 10-18 days, depending on the clone, with environmental conditions as previously described. When root emergence had occurred on most cuttings of a clone, the plantlets were transferred into moistened 'Redi-Earth' soilless medium in containers with clear plastic lids and handled subsequently as described in non-sterile techniques.

RESULTS AND DISCUSSION

Establishment of Aseptic Cultures

Stock plants of all clones grew well in the greenhouse and provided seemingly healthy explant material. However, numbers of lateral buds that grew from stock plants differed greatly among clones, as did amount of senescence of these shoot tips in culture (Table 3). Senescence, seen as a hardening and yellowing of the shoot tips, was either outgrown with repeated transfers, or gradually resulted in shoot tip death. In general, clones with few shoot tips growing on stock plants exhibited greater shoot tip senescence in culture, making these clones difficult to establish *in vitro*. The surface sterilization procedure resulted in a random (<10%) contamination in any batch of explants. Slight browning of cut tissue surfaces occurred with associated medium discoloration, but this disappeared quickly with rapid transferring.

Shoot Tip Culture

Growth

The sequence from sterile establishment on culture medium to initiation of shoot proliferation was similar for explants of all clones, but the time required differed. Preinitiated leaves surrounding the shoot tip expanded first, followed by

Table 3. Micropropagation characteristics of *Malus* clones as determined from this study.

Clone	Establishment of	Shoot Tip Culture		Rooting of Microcuttings					
				Non-sterile[4]			Sterile[5]		
No.	Aseptic Cultures[1]	Growth[2]	Proliferation[3]	No. stuck	No. rooted	%	No. stuck	No. rooted	%
1	easy	moderate	moderate, similar	192	44	23	40	32	80
2	very easy	fast	many, similar	200	101	50	not tested		
3	difficult	slow	moderate, variable	187	20	11	81	43	53
4	easy	moderate	many, similar	192	61	32	not tested		
5	difficult	slow	moderate, variable	220	31	14	186	119	64
6	easy	fast	many, similar	134	110	82	not tested		
7	easy	fast	many, similar	150	62	41	not tested		
8	moderate	slow	moderate, variable	194	42	22	222	139	63

[1]Relative rating scale: very easy=many lateral buds growing on stock plants; easy= >1 batch of explants required due to fewer lateral buds growing; moderate=few lateral buds growing and some shoot tip vitrification in culture; difficult=continued shoot tip vitrification in culture resulting in explant loss.
[2]Relative rating scale: fast=roughly 4 weeks from explant sterilization to new shoot proliferation; moderate=roughly 6-8 weeks; slow= >2 months.
[3]Relative rating scale: moderate=average of 5-15 shoot tips/jar; many=average of 20-30 shoot tips/jar; variable=shoot tips of variable sizes; similar=shoot tips of similar sizes.
[4]Composite rooting percentage using non-sterile procedure, cumulative across times and IBA concentrations.
[5]Cumulative rooting percentages using sterile procedure to initiate roots followed by non-sterline procedure for plantlet development. Microcuttings remained on MS media with 1 mg/l IBA until root initials appeared (11-18 days).

vertical shoot tip elongation. Then new shoot tips formed from the base of the explant. If the explant displayed little or no senescence, time from establishment to initiation of new shoot tips was roughly four weeks with 3-6 transfers to fresh medium. If senescence of the explant occurred, this time period as a solitary expanding shoot tip increased to six weeks to several months with repeated monthly transfers. Typically, however, new shoot tips were finally initiated from these recalcitrant cultures. Table 3 details relative rate of passage of the clones through this stage.

Proliferation

There were clonal differences in numbers and quality of new shoot tips formed in culture seemingly unrelated to the ploidy level or parentage (Table 3). Clone 2 proliferated large quantities, 20-30/jar, of similar-sized shoot tips, while clones 3, 5, and 8 proliferated a few small shoots (later seen to be 'non-rooters') and a few large shoots, characterized by thick, red stems (later seen to be 'potential rooters'). Increasing BA levels has been shown to increase shoot proliferation (Jones, 1967), while decreasing individual shoot size (Lane, 1978). Fine tuning the BA level in the medium for each clone to obtain optimum quantity and quality of shoots would be justified for commercial production.

Rooting Techniques

A. Non-Sterile

This procedure was preferred due to its ease and speed and was the first tested with each clone. If successful, no other procedure was tested for that clone. Preliminary studies comparing IBA dip concentrations showed no effect on rooting percentages, with easy-to-root clones rooting as successfully at 0 ppm IBA as at 500 ppm IBA and difficult-to-root clones rooting poorly across the range of IBA concentrations. Composite rooting percentages, cumulative across times and IBA dip concentrations are presented in Table 3. Clones 2 (50% rooting success), 4 (32%), 6 (82%), and 7 (41%) rooted well, but also importantly produced large numbers of shoot tips as rooting candidates. Clones 1, 3, 5, and 8 had less shoot proliferation and lower rooting success, so more time was required for the non-sterile rooting tests and these clones were also tested using the more laborious sterile procedure.

There were three main causes of microcutting loss. A common cause of loss was rotting of the stem from the base upward. Another was withering and collapse of the stem slightly above the soil surface; this was most commonly seen on small sized cuttings of the poor rooting clones. We believe this to be due to a physiological problem instead of a pathogen, since it was also seen using the sterile rooting technique. Extra calcium was incorporated into the shoot proliferation medium, and foliar sprays of calcium, and MS nutrients, were applied to microcuttings during non-sterile rooting but noticeable strengthening of the stems was not seen. The best solution was to select only thick, reddish stemmed microcuttings as rooting candidates. The third cause of microcutting loss was a fungal pathogen that occasionally killed part or all of the cuttings in a container.

B. Sterile

Clones 1, 3, 5, and 8 were rooted successfully using the sterile technique (Table 3). Preliminary IBA concentration studies showed 1 mg/l IBA incorporated into the MS

medium to be adequate for all clones. Preliminary timing studies showed that cuttings survived best if left in the MS with 1 mg/l IBA medium until root initials appeared, a range of ll-l8 days, then transferring the plantlets to non-sterile conditions for development. Cuttings rooted and survived less successfully if preconditioned on the medium for only five days and then placed in non-sterile conditions. Rooting percentages were also improved in the sterile technique by selection of thick, reddish stemmed rooting candidates.

Greenhouse Observations

All clones have grown well in the greenhouse. Relative growth rate among clones has not been studied; however, clone 2 appears very vigorous. Clone 8 appears most susceptible to powdery mildew followed by Clone 5.

Field Studies

Field trials of 'Starkspur Supreme Delicious' and 'Melrose' on these rootstocks were planted in the spring of 1987 and will be compared to the same cultivars on M.7 and MAC 9 (MARK).

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A COMPARISON OF TWO CIDER PRESSES IN OHIO, 1986

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INTRODUCTION

Apple cider and apple juice sales have more than doubled in the United States since 1974. Imported apple juice concentrate now constitutes more than one-half of all apple juice consumed (1,3).

It is estimated that Ohio produces nearly six million gallons of apple cider per year which has increased from three million gallons since 1980. Therefore, a considerable demand has been created in the wholesale and farm retail markets. There are at least 67 farm cider presses and at least two major cider producers who press in excess of 600,000 gallons per year. Generally, Ohio does not produce sufficient apples to meet the demand, and apples for apple juice must come from out-of-state sources. Blending two or more varieties of fresh sound apples can make a unique quality drink for nearly all seasons of the year. It can be frozen and used when apples are not in season. Up until now, no imported juice concentrate has been used by Ohio producers (3).

Ohio apple cider producers must remain competitive with other available products such as fresh grape juice, canned or frozen apple juice, nectars, and blends of juices as well as soft drinks blended with fruit juices. The cost of apples and the cost of producing apple cider must be known in order to realize a profit or return on investment. Those, who sell cider below the cost of production, will not remain in business over the long-term.

METHODS

Standard budgeting techniques were used to determine the estimated cost and profit per gallon from producing apple cider using either a 24-inch or a 36-inch cider press. Changes in cost and profit per gallon as level of output increases were also examined for both sizes of cider presses.

Machinery costs were based on dealer prices in early 1986. Labor rates, including social security and workmen's compensation payments, were determined from the U.S. Statistical Service Reports and farm family incomes. Repairs were determined from dealers and growers as the average life of materials. The cost of apples was determined from the 1981 to 1985 average price for juice apples ($.04/lb) and for farm-graded fruit ($.08/lb). A bushel of different varieties of fresh apples was assumed to produce 80 percent of its total weight or 3.5 gallons of cider (2,4). The cost of building and insurance was estimated at 7.5 cents per square foot per year. Overhead costs included telephone, taxes, roads, pickup truck, dues, and educational expenses. Wholesale cider production included the transportation of 300 gallons of cider in a returnable container to a location 35 miles away.

A comparison of a 24-inch press (20,000 gallons per year) and a 36-inch press (40,000 gallons per year) was made to show variable and fixed costs. These levels were chosen to represent the major on-farm retail cider production units in Ohio and to demonstrate the price of different capacities necessary in 1986 to break even or make a fair return on investment.

RESULTS AND DISCUSSION

The total cost to produce 20,000 gallons of cider per year from field fresh apples on a 24-inch press was $25,885 or $1.29 per gallon (Table 1). The total cost to produce 40,000 gallons of cider per year from a 36-inch press was $44,047 or $1.10 per gallon (Table 2). At these production levels, the cost per gallon using the 36-inch press was $.19 less than the 24-inch press. As a percentage of total cost, apples account for the largest percentage, 37 and 44 percent, respectively. These apples were purchased at $.04/lb which has been the average price received for juice apples in the past few years. However, many apple growers do not purchase apples for cider, but grade their own apples, put them in cold storage for a few weeks, and then use their own apples for cider.

When apples are graded and stored, the cost of apples increases to $.08/lb. This increased price for apples raises the cost of production of cider using a 24-inch press by $.48 per gallon for a total cost of $1.77 per gallon (Table 3). Cost increases of $.31 per gallon were found for the 36-inch press (Table 4). Thus, apple growers or cider producers who purchase field fresh apples have a comparative advantage over growers who grade and store their apples. At $1.75 per gallon, producers using the 24-inch press and graded apples, had a loss of $.02 per gallon, while producers using the 36-inch press and graded apples had a profit of $.17 per gallon.

In terms of efficiency, the 24-inch press can produce 100 gallons of cider per hour while the 36-inch press can produce 300 gallons per hour. When the total man-hours are compared, the 36-inch press required 171 more total hours (Tables 1 & 2). However, the 36-inch press produced twice as many gallons. In essence, the 24-inch press produced 19.5 gallons per man-hour, while the 36-inch press produced 33.4 gallons per man-hour. In this study, only the press sizes are compared, but the time required to fill gallon jugs remained the same. If there was a faster method to handle the 40,000 gallons per year, there could be greater efficiency in the total operation.

The initial cost of the 36-inch press is nearly twice the cost of the 24-inch press, while the remaining components, except for bulk storage, are the same. As the number of gallons produced increases, the variable cost of apples and

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Table 1. Total cost of production for cider, 24-inch press, juice apples, 20,000 gallons per year, Ohio, 1986.

COSTS AND RETURNS		COST PER UNIT	TOTAL COST	COST/ GALLON	PERCENT OF TOTAL COST
VARIABLE COSTS:					
APPLES	240,240 POUNDS @	$0.0400 /POUND	$9,609.60	$0.480	37.1%
JUGS AND LABELS		$0.1510 /GALLON	3,020.00	0.151	11.7%
SORBATE		0.0028 /GALLON	56.00	0.003	0.2%
LABOR:					
HIRED	934 HOURS@	$7.50 /HOUR	7,008.04	0.350	27.1%
MGMT.	93 HOURS@	$7.50 /HOUR	700.80	0.035	2.7%
REFRIGERATION		$0.0056 /GALLON	112.00	0.006	0.4%
DELIVERY	$0.52/ MILE FOR	70 MILES	2,426.67	0.121	9.4%
TOTAL VARIABLE COSTS			$22,933.11	$1.147	88.6%
OVERHEAD COSTS:					
GENERAL OVERHEAD		$0.04 /GALLON	$800.00	$0.040	3.1%
DEPRECIATION			1310.00	0.066	5.1%
INTEREST			1185.60	0.059	4.6%
REPAIRS			381.20	0.019	1.5%
BUILDING AND INSURANCE			75.00	0.004	0.3%
TOTAL OVERHEAD COSTS			2,951.80	$0.148	11.4%
TOTAL COSTS			$25,884.91	$1.29	100.0%
RETURNS:	$1.75/GALLON		$35,000.00		
RETURN OVER VARIABLE COSTS			$12,066.89	$0.60	
RETURN OVER TOTAL COSTS			$9,115.09	$0.46	

Table 2. Total cost of production for cider, 36-inch press, juice apples, 40,000 gallons per year, Ohio, 1986.

COSTS AND RETURNS		COST PER UNIT	TOTAL COST	COST/ GALLON	PERCENT OF TOTAL COST
VARIABLE COSTS:					
APPLES	480,480 POUNDS @	$0.0400 /POUND	$19,219.20	$0.480	43.6%
JUGS AND LABELS		$0.1510 /GALLON	6,040.00	0.151	13.7%
SORBATE		0.0028 /GALLON	112.00	0.003	0.3%
LABOR:					
HIRED	1089 HOURS @	$7.50 /HOUR	8,167.51	0.204	18.5%
MGMT.	109 HOURS @	$7.50 /HOUR	816.75	0.020	1.9%
REFRIGERATION		$0.0056 /GALLON	224.00	0.006	0.5%
DELIVERY	$0.52 /MILE FOR	70 MILES	4,853.33	0.121	11.0%
TOTAL VARIABLE COSTS			$39,432.79	$0.986	89.5%
OVERHEAD COSTS:					
GENERAL OVERHEAD		$0.04 /GALLON	$1,600.00	$0.040	3.6%
DEPRECIATION			1,900.00	0.048	4.3%
INTEREST			1,945.20	0.049	4.4%
REPAIRS			679.00	0.017	1.5%
BUILDING AND INSURANCE			90.00	0.002	0.2%
TOTAL OVEHEAD COSTS			$4,614.20	$0.115	10.5%
TOTAL COSTS			$44,046.99	$1.10	100.0%
RETURNS:	$1.75/GALLON		$70,00.00		
RETURN OVER VARIABLE COSTS			$30,567.21	$0.76	
RETURN OVER TOTAL COSTS			$25,953.01	$0.65	

Table 3. Total cost of production for cider, 24-inch press, graded apples, 20,000 gallons per year, Ohio, 1986.

COSTS AND RETURNS		COST PER UNIT	TOTAL COST	COST/ GALLON	PERCENT OF TOTAL COST
VARIABLE COSTS:					
APPLES	240,240 POUNDS @	$0.0800/POUND	$19,219.20	$0.961	54.1%
JUGS AND LABELS		$0.1510/GALLON	3,020.00	0.151	8.5%
SORBATE		0.0028/GALLON	56.00	0.003	0.2%
LABOR:					
HIRED	934 HOURS @	$7.50/HOUR	7,008.04	0.350	19.7%
MGMT.	93 HOURS @	$7.50/HOUR	700.80	0.035	2.0%
REFRIGERATION		$0.0056/GALLON	112.00	0.006	0.3%
DELIVERY	$0.52 /MILE FOR	70MILES	2,426.67	0.121	6.8%
TOTAL VARIABLE COSTS			32,542.71	$1,627	91.7%
OVERHEAD COSTS:					
GENERAL OVERHEAD		$0.04/GALLON	$800.00	$0.040	2.3%
DEPRECIATION			1310.00	0.066	3.7%
INTEREST			1185.60	0.059	3.3%
REPAIRS			381.20	0.019	1.1%
BUILDING AND INSURANCE			75.00	0.004	0.2%
TOTAL OVERHEAD COSTS			$2,951.80	$0.148	8.3%
TOTAL COSTS			$35,494.51	$1.77	100.0%
RETURNS:	$1.75/GALLON		$35,000.00		
RETURN OVER VARIABLE COSTS			$2,457.29	$0.12	
RETURN OVER TOTAL COSTS			($494.51)	($0.02)	

Table 4. Total cost of production for cider, 36-inch press, graded apples, 40,000 gallons per year, Ohio, 1986.

COSTS AND RETURNS		COST PER UNIT	TOTAL COST	COST/ GALLON	PERCENT OF TOTAL COST
VARIABLE COSTS:					
APPLES	960,960 POUNDS @	$0.0800 /POUND	$76,876.80	$0.961	68.1%
JUGS AND LABELS		$0.1510 /GALLON	12,080.00	0.151	10.7%
SORBATE		0.0028 /GALLON	224.00	0.003	0.2%
LABOR:					
HIRED	1089 HOURS @	$7.50 /HOUR	8,167.51	0.102	7.2%
MGMT.	109 HOURS @	$7.50 /HOUR	816.75	0.010	0.7%
REFRIGERATION		$0.0056 /GALLON	448.00	0.006	0.4%
DELIVERY	$0.52/MILE FOR	70 MILES	9,706.67	0.121	8.6%
TOTAL VARIABLE COSTS			$108,319.73	$1.354	95.9%
OVERHEAD COSTS:					
GENERAL OVERHEAD		$0.04 /GALLON	$3,200.00	$0.040	2.8%
DEPRECIATION			1,900.00	0.024	1.7%
INTEREST			1,945.20	0.024	1.7%
REPAIRS			679.00	0.008	0.6%
BUILDING AND INSURANCE			90.00	0.001	0.1%
TOTAL OVERHEAD COSTS			$4,614.20	$0.058	4.1%
TOTAL COSTS			$112,933.93	$1.41	100.0%
RETURNS:	$1.75/GALLON		$140,000.00		
RETURN OVER VARIABLE COSTS			$31,680.27	$0.40	
RETURN OVER TOTAL COSTS			$27,066.07	$0.34	

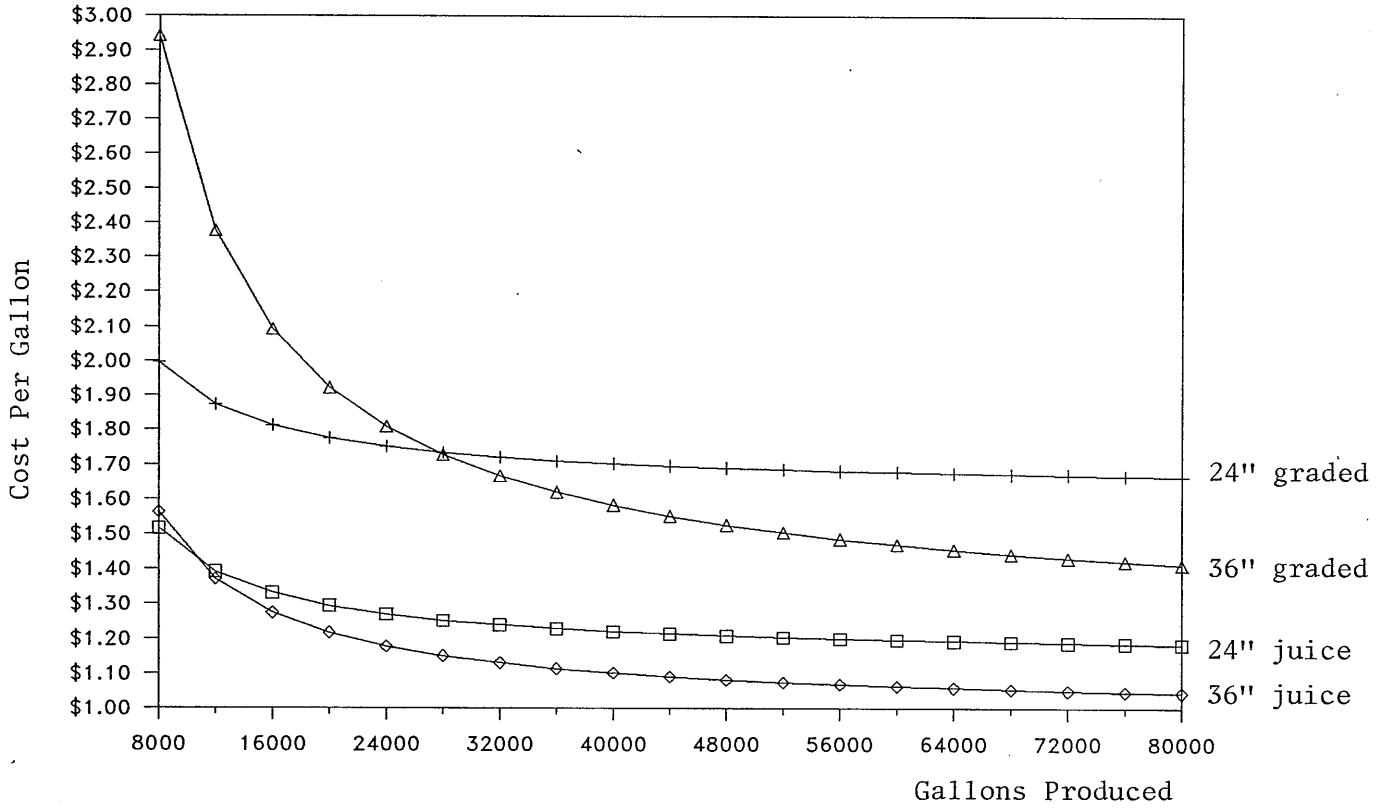

Figure 1. Total cost per gallon for cider.

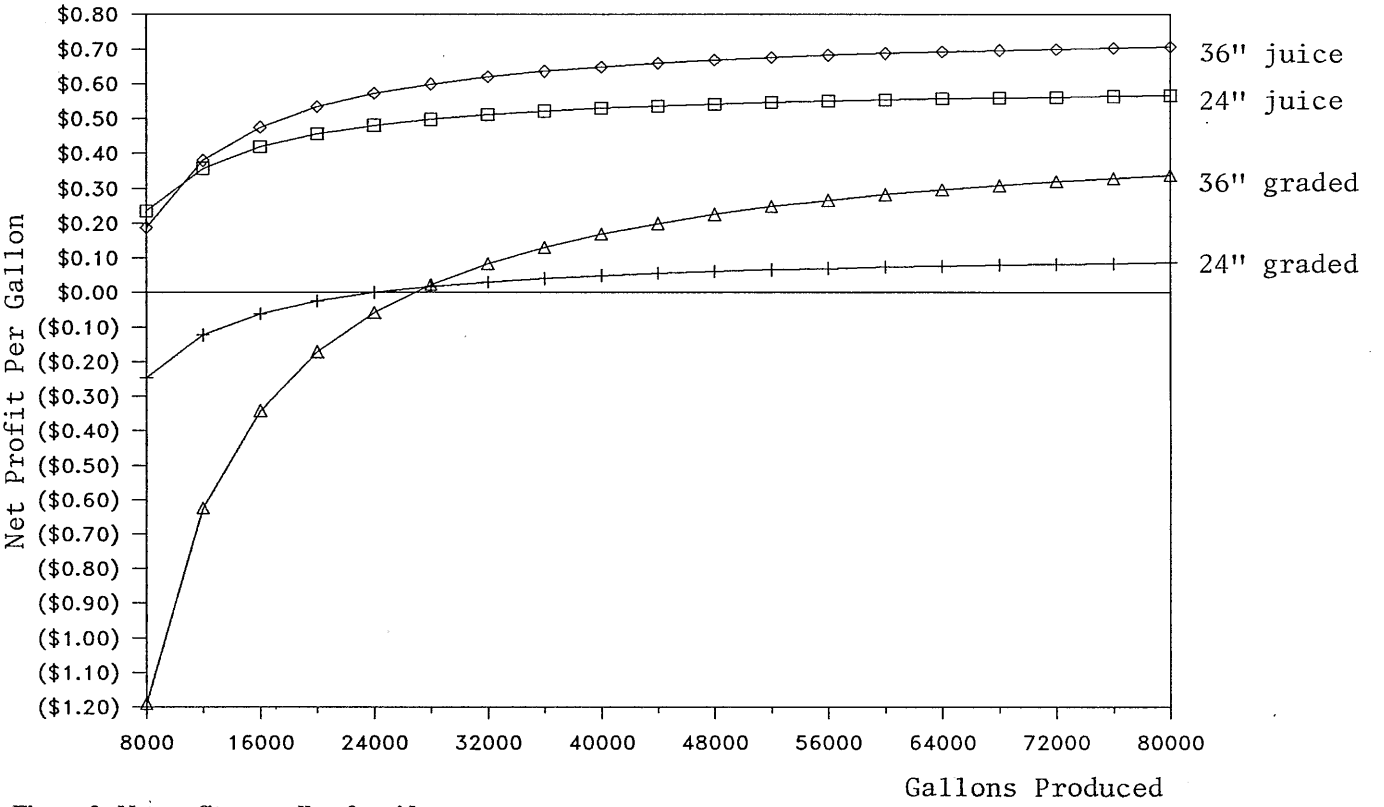

Figure 2. Net profit per gallon for cider.

labor remains the same, but the total cost per gallon decreases (Figure 1). Since these variable costs represent the highest percentage of total costs, there is a point where maximum efficiency is reached with the equipment used. For the 24-inch press with juice apples, this would be near 20,000 gallons per year, while the 36-inch for the graded fruit is near 32,000 or more gallons. The net profit per gallon using graded fruit on either press will be positive near 28,000 gallons (Figure 2). However, the 36-inch press appears to give greater profits if 36,000 gallons are produced annually. If juice apples are used, the 36-inch press appears to give higher profit with 20,000 or more gallons per year.

SUMMARY AND CONCLUSIONS

On-farm cider producers should consider the cost of apples (raw product), equipment and other costs when they decide to produce cider at a profit. Purchasing juice apples is less expensive than graded and stored (few weeks) fruit. Growers who have a need for small amounts of cider may wish to have a commercial cider operation produce the cider for them. For others who wish to produce large volumes of cider each season (25,000 to 50,000 gallons annually), a press making 300 gallons per hour is more efficient at large volumes than one that presses 100 gallons per hour.

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